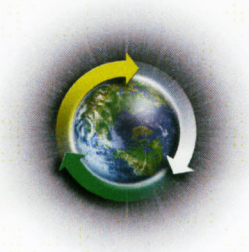

Engineering Alternative Studies for Separations NEPA Data Input Report

EAS-Q-NEP-G-00001

April 2008
Revision 3

UNCLASSIFIED
DOES NOT CONTAIN
UNCLASSIFIED CONTROLLED
NUCLEAR INFORMATION

ADC & Reviewing Official: Cassandra Bayer/Engr
(Name and Title)

Date: 4/4/08

APPROVALS

Prepared by: Cassandra Bayer — 4/7/08

C.L. Bayer
Senior Engineer, Systems Engineering & Integration, SRS

Date

Approved By: R. L. Geddes — 4/7/08

R. L. Geddes
EAS Process Engineering Manager, SRS

Date

Approved By: S. G. McConnell by R. L. Geddes — 4/7/08

S. G. McConnell
EAS Program Manager (Acting), SRS

Date

Approved By:

D. P. Stout
Director LWR Spent Fuel Separations, DOE-NE

Date

Summary of Changes

Issue Date	Revision	Description
01/18/07	A	Initial Draft
01/29/07	B	Incorporation of INL Comments
02/08/07	C	Incorporation of Tetra Tech Comments and data input to tables
03/30/07	0	Initial Issue of Report for GNEP PEIS
06/19/07	1A	Revised to Incorporate DOE Comments and Additional Information
07/27/07	1B	Incorporation of comments and electro-refining data
8/27/07	2	Incorporation of comments from INL and DOE. Global change from electro-refining to electrochemical processing.
11/14/07	2	Corrected typographical error on page 74 (I129 activity). Retransmitted to DOE/NE for final approval signatures.
11/29/07	2	- Added statement in last paragraph on page 11 concerning a co-located fast reactor SNF recycling facility. - Added note on page 15, Table 2, concerning the basis for the 100 day per year operation for a 100 MTHM/year facility. - Corrected values in Table 12 for non-hazardous liquid effluents (sanitary and industrial water). - Corrected values in Table 24 for consistency with updated Flowsheet and product specifications. - Reduced number of HLW shipments in Table 36 based on current waste form and package. - Corrected Table A-1 per discussion with DOE HQ. Resubmitted for DOE/NE approval signatures.
04/02/08	3	- Added text on purpose of 100 MTHM/year facility - Added text on how waste generation rates were determined - Added additional area needed for waste facilities, if necessary - Added text on the different of area between UREX+1a and COEX facility. - Corrected daily rate for HLW for 800 MTHM/year facility - Added References

Table of Contents

LIST OF FIGURES

LIST OF TABLES

Acronyms

Acronym	Definition
ARF	Airborne Release Fractions
Am	Americium
Ba	Barium
BWR	Boiling Water Reactor
C	Carbon
CCD-PEG	Chlorinated Cobalt Dicarbollide/Polyethylene Glycol
CFR	Code of Federal Regulations
Ci	Curie
Cm	Curium
Co	Cobalt
Cs	Cesium
D&R	Dismantlement and Removal
DOE	Department of Energy
DOT	Department of Transportation
DWPF	Defense Waste Processing Facility
EAS	Engineering Alternative Studies
ECF	Entry Control Facility
EPA	Environmental Protection Agency
FAST	Fluorinel Dissolution Process and Fuel Storage
FP	Fission products
FPEX	Fission Product Extraction
FPR	Fuel Processing Restoration
GNEP	Global Nuclear Energy Partnership
GTCC	Greater-Than-Class C
GWh	Giga Watt hour
H-3	Tritium
HEPA	High Efficiency Particulate Air
HEU	Highly Enriched Uranium
HLW	High Level Waste
HVAC	Heating, Ventilation and Air Conditioning
I	Iodine
INL	Idaho National Laboratory
IWTU	Integrated Waste Treatment Unit
KW	Kilowatt
lb	Pound
LLW	Low Level Waste
LWR	Light Water Reactor
µCi	Microcurie

Acronym	Definition
MPC	Multi Purpose Canister
MTHM	Metric Ton Heavy Metal
MVA	Million Volt Amps
MWh	Mega Watt hour
Nb	Niobium
nCi	NanoCurie
NEPA	National Environmental Policy Act
Ni	Nickel
Np	Neptunium
NRC	Nuclear Regulatory Commission
PEIS	Programmatic Environmental Impact Statement
Pu	Plutonium
PWR	Pressurized Water Reactor
Rb	Rubidium
RBOF	Receiving Basin for Offsite Fuels
RCRA	Resource Conservation and Recovery Act
Ru	Ruthenium
scf	Standard Cubic Feet
SNF	Spent Nuclear Fuel
SNM	Special Nuclear Materials
Sr	Strontium
SRS	Savannah River Site
TALSPEAK	Trivalent Actinide Lanthanide Separations by Phosphorus-reagent Extraction from Aqueous Complexes
Tc	Technetium
TRU	Transuranic
TRUEX	Transuranic Extraction
U	Uranium
UDS	Un-dissolved Solids
UO_3	Uranium Trioxide
UREX	Uranium Extraction
Zr	Zirconium

1.0 Introduction

The Department of Energy's (DOE) Global Nuclear Energy Partnership (GNEP) is a comprehensive strategy to increase United States and global energy security, reduce the risk of nuclear proliferation, encourage clean energy development around the world, and improve the environment. GNEP recommends that the United States move from a once-through fuel cycle to a new approach that includes recycling of spent nuclear fuel (SNF) without separating the transuranic components of spent nuclear fuel. This capability would employ advanced technologies to recover and reuse fuel resources and reduce the amount of wastes requiring permanent geological disposal.

Under the GNEP recycling could accomplish:

- Separation of high purity uranium from the spent fuel that would allow recycle for re-enrichment or for other use or disposition
- Separation and immobilization of long-lived fission products, technetium, and iodine for disposal in a geological repository
- Extraction and temporary storage of short-lived fission products (cesium and strontium) to meet the requirements for disposal
- Separation of transuranic (TRU) elements for fabrication into fuel for an advanced recycling reactor. The advanced recycling reactor would consume the transuranic elements and recover their energy.

The proposed nuclear fuel recycling center would separate the SNF discharged from Light Water Reactors (LWRs) and advanced recycling reactors into its reusable components and waste components and manufacture new nuclear fuel using reusable components that still have the potential for use in nuclear power generation. The proposed nuclear fuel recycling center consists of the LWR SNF recycling facility, transmutation fuel fabrication facility, and the fast reactor SNF recycling facility. This report provides the National Environmental Policy Act (NEPA) information for a LWR SNF recycling facility which is part of the proposed nuclear fuel recycling center. This facility is just part of the overall GNEP program.

The LWR SNF recycling facility will be a self-sufficient operation located at a Greenfield site in the United States. The goal of the facility would be to separate the potentially reusable constituents (uranium and transuranic elements) from the non-reusable constituents (e.g., fuel element structural materials and fission products) in LWR SNF. There are two types of LWRs, Pressurized Water Reactors (PWRs) and Boiling Water Reactors (BWRs). The reusable constituents would be used to make transmutation fuel for an advanced recycle reactor and, possibly, other reactor fuels (e.g., uranium could be re-enriched and made into LWR fuel). Non-reusable constituents would be converted to waste forms for eventual disposal in a geologic repository or for other long-term storage or disposal, as appropriate.

2.0 Recycling Facility Operations and Requirements

The recycling facility will receive and manage SNF, dissolve the fuel core from inside the cladding material, and use various extraction steps to separate the various components of SNF. The best available engineering information for the NEPA Programmatic Environmental Impact Statement (PEIS) is presented in this report. Reasonable assumptions have been made for the purpose of developing the NEPA analysis data such that the construction requirements and operational characteristics would envelope all anticipated environmental impacts over the planned 40 year operation. The assumption has been made that the LWR SNF would be recycled using the aqueous UREX[1] separation processes. Electrochemical processing technologies are also a likely option for recycling LWR SNF and are discussed in this document.

Key facility operations for recycling of LWR SNF include:

- SNF receipt, storage and transfer
- SNF preparation and head-end treatment
- Processing and purification
- Product Handling - solidification, packaging, storage and shipping of uranium and U/TRU oxides
- Waste Processing and Handling– packaging, storage and preparation for shipment of wastes

Key process support systems include:

- Remote handling systems
- Process controls and data management systems
- Heating Ventilation and Air Conditioning (HVAC) systems
- Health physics
- Safeguards and security systems
- Material control and accountability
- Sampling and analysis systems

The facility will include all utilities and infrastructure necessary for the operation of the facility. Separate co-located facilities are planned to utilize the uranium/transuranic product material to fabricate fuel for an advanced recycle reactor and to recycle the spent advanced recycle reactor, also know as a fast reactor, fuel.

[1] UREX+1a is used as a baseline for this document, other the separations could be used (Table 1).

The recycling facility operations are shown schematically in Figure 1 for the UREX +1a process[2], and in Figure 2 for the electrochemical processing option.

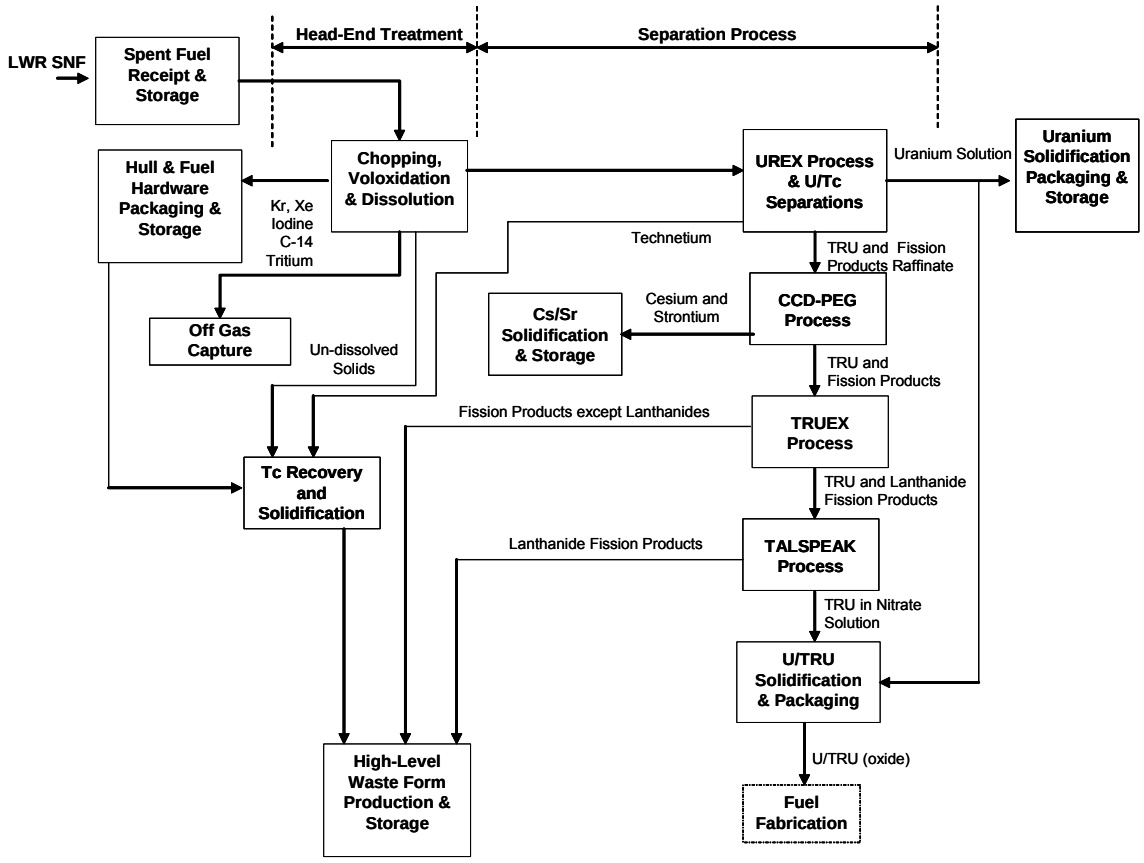

Figure 1 UREX+1 Process Diagram

For all potential recycling options, the SNF assemblies are received via truck or rail from a variety of off-site commercial nuclear facilities. These materials are stored pending preparation for separations processing. Fuel bundles are prepared for separations processing in the Head End process, where fuel assemblies are chopped into smaller pieces.

[2] The anticipated separations process is UREX+1a which is a series of four solvent-extractions that perform the following operations: (1) recovery of uranium and technetium (UREX), (2) recovery of cesium and strontium (CCD-PEG), and (3) recovery of transuranic and rare earth elements (TRUEX), and (4) separation of transuranic elements from the rare earths (TALSPEAK).

The recycling facility operations are shown schematically in Figure 2 for electrochemical processing.

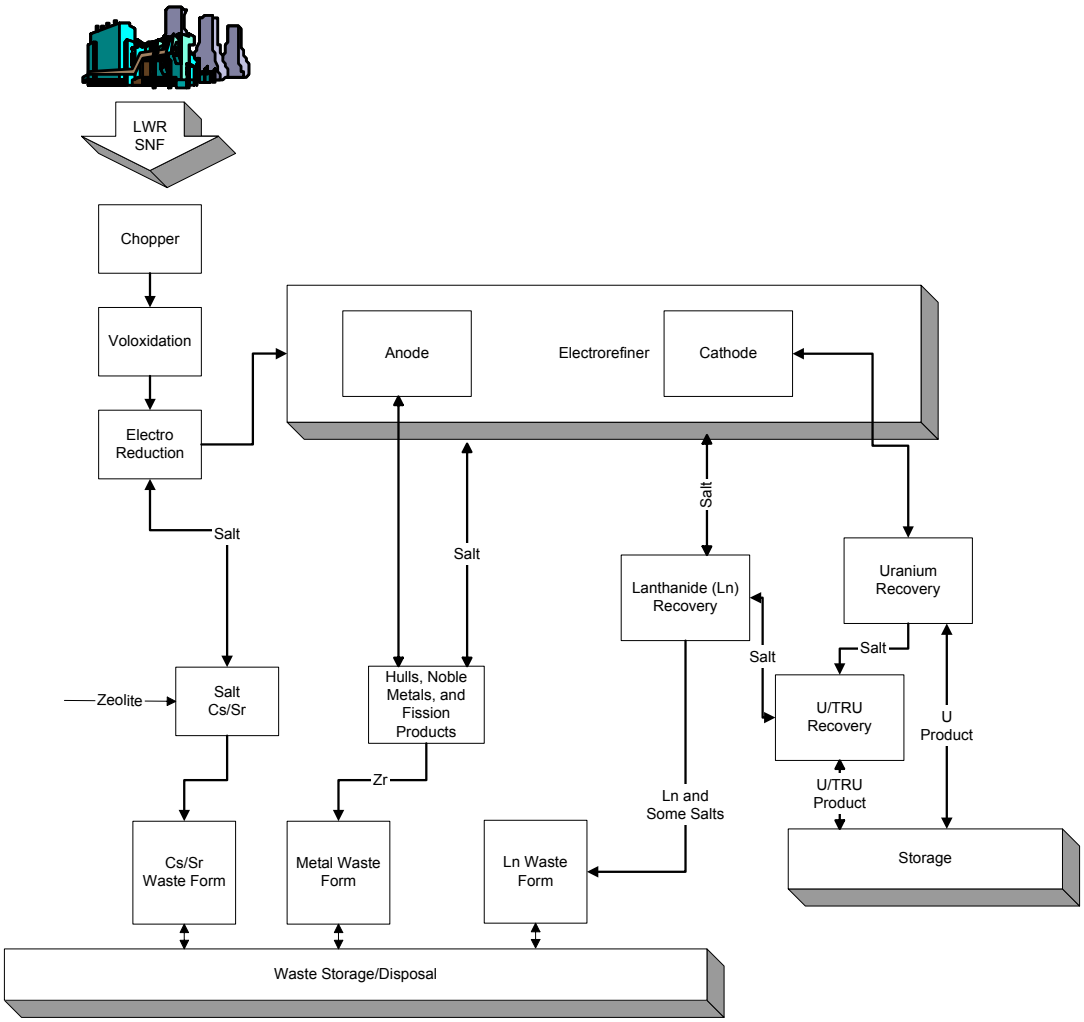

Figure 2 Electrochemical Processing Diagram

In the UREX aqueous processes, the chopped fuel is voloxidized to remove the fuel, in the form of an oxide, from the cladding. The dissolved fuel is then fed to the separations process. In electrochemical processing, the oxide must be converted to a metal prior to the separations and purification steps.

The separations processes are designed to separate waste materials (fission products, rare earth elements, and other contaminants) from the actinide elements (uranium, neptunium, plutonium, americium, and curium) which are used in the fabrication of new fuels. Materials from the process to be used in fuel fabrication will be packaged in DOE certified containers for storage and shipped to the fuel fabrication facilities for further processing.

The specifications for the advanced recycling reactor fuel have not been finalized. Therefore, modifications to the flowsheet chemistry and head-end process treatment systems are expected during the course of technology development for the future advanced recycling reactor fuels. There are various UREX processes that could be used to separate the LWR SNF. Table 1 provides a summary of the different UREX processes. Any one of these processes could be used in lieu of the UREX+1a described in this document. The environmental impact differences between the various processes should be minor.

Table 1 Suite of UREX+ Processes

Process	Prod.#1	Prod.#2	Prod.#3	Prod.#4	Prod.#5	Prod.#6	Prod.#7
UREX+1	U	Tc	Cs/Sr	TRU+Ln	FP		
UREX+1a	U	Tc	Cs/Sr	TRU	All FP		
UREX+2	U	Tc	Cs/Sr	Pu+Np	Am+Cm+Ln	FP	
UREX+2a	U	Tc	Cs/Sr	U+Pu+Np	Am+Cm+Ln	All FP	
UREX+3	U	Tc	Cs/Sr	Pu+Np	Am+Cm	All FP	
UREX+3a	U	Tc	Cs/Sr	U+Pu+Np	Am+Cm	All FP	
UREX+4	U	Tc	Cs/Sr	Pu+Np	Am	Cm	All FP

At each stage in the overall process, materials are analyzed for a variety of process parameters such as chemical and isotopic composition, particle size distribution, density, uniformity, and physical dimension. These analyses can be used for a variety of purposes such as quality assurance and process control, material control and accountability, and criticality safety. Evolved gases, and waste liquids and solids are also analyzed and treated to meet established Environmental Protection Agency (EPA) criteria. Some of these analyses are performed in-process, and some involve samples taken for analysis at a certified on-site or off-site analytical laboratory. Storage capacity is designed to ensure that throughput is not limited by materials availability.

Waste materials from the process areas are appropriately treated and packaged for storage, shipment and disposal as discussed in Section 3.0 for aqueous processing and Section 4.0 for electrochemical processing.

2.1 Operations Basis

The reasonable inventory of nuclear material contained in the various separations and storage processes is presented in Table 2 for the three alternatives being evaluated for aqueous separations, a small 100 metric tons of heavy metal (MTHM) per year facility, an 800 MTHM per year facility and two existing DOE facilities (see Section 2.2). A 300 MTHM/year electrochemical processing recycling facility is also being considered. The mass basis is the initial heavy metal (i.e., actinide) content expressed as MTHM. The fission product content depends on the burn-up of fuel in the reactor (corresponding to power produced per unit mass of fuel) and on the decay products during cooling. The average calculated distribution of elements and isotopes in the spent nuclear fuel to be received is presented in Appendix A.

Using a 240 day per year operation time, the baseline process throughputs for 800 MTHM/year aqueous recycling facility are calculated using a maximum 3.33 MTHM of SNF per day. The throughput of a small 100 MTHM per year facility would be 1.0 MTHM of SNF per day at 100 days operation per year. The throughput of the two existing DOE facilities is expected to be bounded by 1.0 MTHM of SNF processed per day at 100 days per year based on the size of the existing facilities under consideration. Using a 240 day per year operation time, the baseline process throughputs for 300 MTHM/year electrochemical processing recycling facility are calculated using a maximum 1.6 MTHM of SNF per day. These process throughputs are used to develop baseline equipment designs and layouts, which, in turn, are used to develop a theoretical plan for the entire facility. At this early planning stage, there are many engineering details that have not been defined. However, the process throughputs used in this report are selected to bound all possible processing inventories that would reasonably be required to support such an operation. Flow sheets and associated material balance, product/waste distribution, and estimates for reagents and utilities have been developed.

Table 2 Nuclear Materials for Defining the Operations Basis

Facility Description		100 MTHM/year Greenfield Facility	800 MTHM/year Facility	Existing DOE Facilities[2]	300 MTHM/year Electrochemical Processing Facility
Process Area		**Annual Material Processing Throughput** (60 GWD/MTHM, 5 year cooled, spent Light Water Reactor (LWR) commercial spent fuel)			
SNF Storage		• At the baseline rate of 100 MTHM/yr, the 2-year storage capacity equates to 456 PWR fuel assemblies.[1] • Isolate and manage a minimum of 5% fuel assemblies received that may be damaged or otherwise unsuitable for near-term processing.	• At the baseline rate of 800 MTHM/yr, the 2-year storage capacity equates to 3,640 PWR fuel assemblies.[1] • Isolate and manage a minimum of 5% fuel assemblies received that may be damaged or otherwise unsuitable for near-term processing.	• At the baseline rate of 100 MTHM/yr, the 2-year storage capacity equates to 456 PWR fuel assemblies.[1] • Isolate and manage a minimum of 5% fuel assemblies received that may be damaged or otherwise unsuitable for near-term processing.	• At the baseline rate of 300 MTHM/yr, the 2-year storage capacity equates to 1,366 PWR fuel assemblies.[1] • Isolate and manage a minimum of 5% fuel assemblies received that may be damaged or otherwise unsuitable for near-term processing.
Operation Time		• 100 days per year[3]	• 240 days per year	• 100 days per year[3]	• 240 days per year
Product Storage	UO_3	Store 1 years' production of UO_3			
	U/TRU	Store 1 years' production of U/TRU			
Waste Storage		On-site storage capacity for up to 1 years' production of waste.			

1 –PWR assemblies are also the most prevalent type of assembly used in the nuclear industry and would be the bounding condition for storage space considerations.
2 – The throughput for the two existing DOE facilities being evaluated is the same. The facilities being considered are F-Canyon and Fuel Processing Restoration (see Section 2.2)
3 – The 100 MTHM/year facilities are assumed to be engineering scale and operated for a shorter period

per year.

The purpose of a 100 MTHM/year LWR SNF facility would be to test at an engineering scale an integrated separations flowsheet that produces the actinide products required by Advanced Fuel Cycle Initiative (AFCI) and GNEP technology deployment activities. Actinide products would be needed for subsequent fuel qualification experiments through the fabrication of lead test assemblies. In addition, it would be possible to demonstrate the capability to prepare all waste forms acceptable from an environmental and human health standpoint. Large scale operations here and elsewhere have been with the PUREX process, producing pure plutonium and used only for LWR recycle. Some waste disposal methods currently operated on a large scale would not be acceptable for a facility licensed in the United States.

There are two existing facilities under consideration, F-Canyon at the Savannah River Site (SRS) and Fuel Processing Restoration (FPR) Facility at Idaho National Laboratory. The main differences would be in construction and layout details. The construction would include facility demolition, system upgrades and modifications in addition to building of new facilities. The FPR facility would require more new construction than the F-Canyon facility. The existing facilities would utilize existing site infrastructure and balance of plant services for power, steam, water and waste handling. The emissions, product and waste streams for an existing DOE facility would be similar to the 100 MTHM/year Greenfield facility. Additional information for each of the existing facilities is provided in Section 2.2.

2.2 Existing DOE Facilities

2.2.1 Savannah River Site F-Canyon

F-Canyon, located at the SRS in South Carolina, recovered uranium and plutonium from irradiated nuclear fuel and targets using the Plutonium-Uranium Extraction (PUREX) process. The irradiated fuel and targets were dissolved and then processed though solvent extraction operation to chemically separate uranium and plutonium from fission products and one another. The plutonium was converted to metal and the depleted uranium was converted to uranium trioxide (UO_3).

The F-Canyon has two distinct sides designated as “hot” and “warm” canyons. The more highly radioactive processing operations were performed in the “hot” canyon while the less radioactive operations were performed on the “warm” side. The canyon shared a central operation and service section. Equipment and fuel were transported and maintained by means of remote controlled cranes. F-Canyon was designed for remote operation from a control room, for remote maintenance, and for almost unlimited reconfiguration of piping and tanks.

Nuclear material reprocessing in the F-Canyon ceased in 2002. Parts of F-Canyon have been deactivated; however utilities such as normal and emergency power, steam, chilled water and compressed air remain in service. The building infrastructure remains in good condition.

Given the flexible design of F-Canyon, it is reasonable to expect that the facility can be modified to accept the UREX (or similar) process and any subsequent changes to enhance mission, safety, or efficiency. Although the physical structures are in good condition, restoration of F-Canyon will be complex. It is likely that many process and support systems will require replacement. Due to prior actinide operations, dismantlement and removal (D&R) of existing equipment, construction, and startup will require disciplined radiation, contamination control and waste management practices.

The F-Canyon alternative takes advantage of many other existing SRS facilities, most prominently the Receiving Basin for Offsite Fuels (RBOF) fuel storage pools and the Defense Waste Processing Facility (DWPF) high level waste vitrification and storage facilities. RBOF will require some modifications and upgrades to receive commercial SNF.

An overview of the F-Canyon available infrastructure and modification necessary are provided in Table 3.

2.2.2 Fuel Processing Restoration Facility (FPR)

The FPR is located at the Idaho National Laboratory (INL) in Idaho. The facility was intended to recover highly enriched uranium (HEU) from spent naval nuclear fuel, but was never utilized. The building was about 50 percent complete when construction was stopped in 1992. FPR was discontinued in a manner that preserved the facility for possible future re-use.

FPR has several underground cells that can be used for remote separations processing. The process cells have removable roof hatches and an overhead maintenance area for crane access, but have little remote maintenance capability. A series of shield windows, cranes and manipulators facilitate equipment operation and maintenance which are located in a corridor adjacent to the cells.

FPR is an uncontaminated and substantially empty facility, with minimal D&R required. Modifications and equipment placement in FPR would be done in a “clean” environment. FPR was initially designed for HEU reprocessing and not as a facility that would handle high actinide material, therefore the facility lacks the required hardened above ground structure and tertiary ventilation. In addition, the FPR design concept placed most active equipment outside of the cells where maintenance and replacement could be accommodated. The large process cells were intended for static equipment where maintenance and replacement would be infrequent or unanticipated. This concept potentially limits facility and process flexibility since process evolution and upgrades may not be possible in such areas following initial hot operations.

A second INL facility, the Fluorinel Dissolution Process and Fuel Storage (FAST) Facility, would be utilized for SNF receipt and storage, head end treatment and waste treatment. A significant modification to the FAST facility would be required to install

new hot cells for head end treatment, which includes shearing and voloxidation, and fuel dissolution, metal waste treatment and fission product vitrification.

An overview of the FPR available infrastructure and modifications necessary are provided in Table 3.

Table 3 Existing Facilities Overview

	F-Canyon	**FPR**
Location	SRS in South Carolina	INL in Idaho
Existing Infrastructure	• RBOF SNF Pools • Rail line to F-Area • Hot and Warm Canyons • FB-Line vault • Multi-purpose Processing Facility (MPPF) • DWPF • Analytical Laboratories • Effluent Treatment Facility • Balance of Plant Operations/Facilities	• FAST SNF Pools • FPR Cells (partial) • Analytical Laboratories (partial) • Integrated Waste Treatment Unit (IWTU) • Balance of Plant Operations/Facilities
Modifications Needed	• Restart RBOF • Refurbish 70-ton cask • D&R and refurbishment of canyon • New U/TRU hot cell • New Cs/Sr tube loadout facility • New waste storage • Inter-area transfer to DWPF	• New FAST hot cells • Completion and startup of FPR • New product and waste storage • IWTU upgrades for Cs/Sr solidification • Inter-area transfer lines
Approximate Cost for Modifications	$1.3 to 1.9 Billion	$5.4 to 7.9 Billion

2.3 Process Descriptions

Due to the intense radiation field exhibited by the spent fuel and the associated processing operations, all of extraction operations will be performed in shielded, remotely operated maintained environment (e.g., hot cell or canyon) utilizing manipulators and other alternative remote handling equipment. Viewing to support the remote operations will be provided via shielding windows, cameras, or some combination of the above.

2.3.1 SNF Receipt, Storage and Transfer

Spent nuclear fuel assemblies will arrive onsite via commercially licensed transport from commercial LWR nuclear reactor facilities. The transport vehicle will consist of a special railcar or special truck with casks specifically designed for the safe and secure transport of SNF. All shipping casks will be United States Nuclear Regulatory Commission (NRC) licensed, and contents will be within license constraints.

The fuel transportation casks will be received and staged in a receipt area where contamination surveys and other integrity checks can be performed. The facility will have both wet-and dry-fuel handling capability and storage for SNF. Once the casks are unloaded spent fuel canisters can be either transferred to dry storage or opened and placed in wet storage (i.e., spent fuel pool). Once removed from the storage casks, the individual spent fuel assemblies will be inspected prior to processing.

Capability to quarantine, repackage or delay processing of a limited amount of fuel will be provided as necessary to handle a leaking assembly or a bundle damaged during shipment or unloading. Inspected SNF fuel assemblies will be retrieved from storage and transferred to an area for subsequent processing.

The upper bounding alternative allows for a maximum of 800 MTHM of LWR fuel to be recycled each year. This would equate to approximately 1,820 assemblies per year. The wet and dry storage areas will have the capability to store approximately 1,820 fuel assemblies each. The facility baseline is to be able to store 2 years throughput in the combined wet and dry storage areas. Table 4 provides the yearly storage volume for assemblies for each of the alternatives being evaluated in this report.

Table 4 Maximum Number of Assemblies Processed Annually

	100 MTHM/year Facility (Greenfield, F-Canyon and FPR)[2]	800 MTHM/year Facility	300 MTHM/year Electrochemical Processing Facility
Annual Number of PWR[1] SNF Assemblies	228	1,820	683

1 – only values for PWR are being given since they are the more prominent of the LWR fuel types. BWRs are smaller than PWRs and will fit into the same storage locations.
2 – The throughput for the two existing DOE facilities being evaluated is the same. The facilities being considered are F-Canyon and Fuel Processing Restoration (see Section 2.2)

2.3.2 Head End Treatment

SNF must be mechanically handled and chopped and de-clad prior to treatment in the separations processes. The generalized head end treatment processing is illustrated in Figure 3. SNF fuel assemblies will be remotely received for further processing in a shielded receipt and storage area. The entire assembly will then be fed intact to a

shear operation. The irradiated spent fuel rods will have internal pressure, which will be relieved during the shearing operation. Provisions will be made to capture radioactive gases as they are released from the rods to prevent spreading contamination beyond the initial control barrier or zone, and to control environmental gaseous releases.

The shear process will generate fuel rod segments on the order of 1-1/2 to 3 inches long. The fuel rods segments will then be transferred to a voloxidation[3] process. Voloxidation converts ceramic fuel to a powdery form more suitable for dissolution or electrolytic reduction, while the fission product gases such as tritium, iodine and carbon-14 are released and are sequestered in the head end off-gas capture process.

2.3.2.1 Aqueous Processes

After voloxidation, for the aqueous processes, the fuel is mechanically separated from the hulls. The fuel will be transferred to the dissolvers and reacted with nitric acid to dissolve the spent fuel oxides. The dissolver solution will be fed to the separation processes. The un-dissolved solids (UDS) remaining after secondary dissolution will be combined with the Tc alloy waste form and packaged for disposal at a geologic repository.

The spent fuel hulls and other remaining fuel assembly hardware (e.g., guide tubes, spacer grids, and tie rods) will be further treated with nitric acid and supplemental washes as necessary to remove excess material that may not have been voloxidized and removed during mechanical separation. After washing, the metal will be rinsed and dried. Parts of the fuel bundle removed prior to the dissolving operation (e.g. end plates), are prepared for disposition by use of acid washes and rinses as necessary. A portion of the metal will be transferred to Tc Solidification to be used in the alloying process. The remaining metal wastes from the fuel assemblies will be combined, compacted and packaged for storage and disposal. The metal waste will be remotely handled due to presence of highly radioactive activation products.

[3] The process for oxidizing irradiated fuel pellets to release the volatile fission products (iodine, xenon, C-14 as CO_2, krypton and tritium) from the pellets.

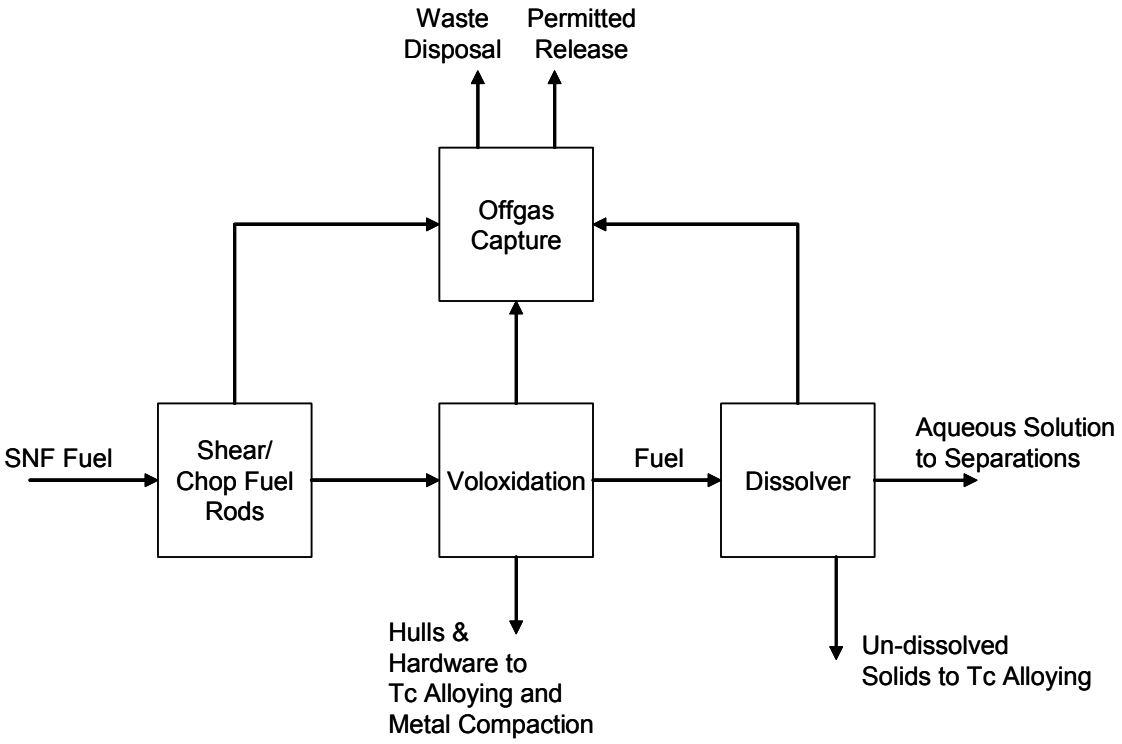

Figure 3 Generic Head End Processing Block Flow Diagram for Aqueous Processing

2.3.2.2 Electrochemical Processing

In electrochemical processing, after voloxidation, the spent fuel hulls are not separated from the oxide. Parts of the fuel bundle removed prior to voloxidation (e.g. end plates) are combined with other metal wastes, melted into ingots and packaged for storage and disposal. The metal waste will be remotely handled due to presence of highly radioactive activation products.

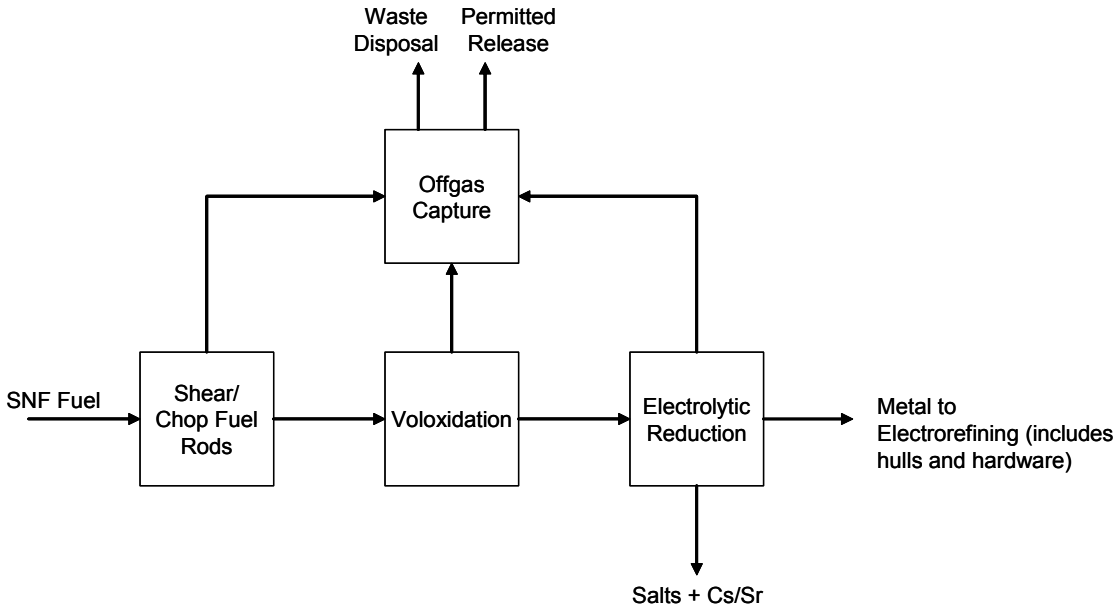

Figure 4 Generic Head End Processing Block Flow Diagram for Electrochemical Processing

The oxide must be reduced to a metal so that the material can be separated and purified in the electrochemical process. This is done using electrolytic reduction in a molten salt electrolyte. Cesium (Cs), strontium (Sr), barium (Ba) and rubidium (Rb) form chlorides that are removed from the salt via ion exchange. The cleaned salt is reused. The zeolite containing the Cs, Sr, Ba, and Rb will be converted to a stable waste form and packaged for disposal.

2.3.3 SNF Aqueous Separation Process

The UREX+1a separation process is a series of four solvent extraction (Figure 5) operations to separate products and waste. The separations are being performed to extract and purify uranium and transuranic products from the SNF, which will be blended together to form a feed stock for advanced recycle reactor fuel. As part of this process the partitioned waste products will be treated and disposed of accordingly. The first solvent extraction (UREX) separates uranium and technetium from the dissolved spent nuclear fuel solutions (fission products, lanthanides, TRU elements), and from each other. The next extraction, CCD-PEG, which is named for the extractant used, separates cesium and strontium from the UREX raffinate[4]. Fission product extraction (FPEX) is an alternative to CCD-PEG that can be used to separate cesium and strontium. The third extraction (TRUEX) separates the transuranics (TRU) and

[4] Raffinate is the aqueous stream that remains after the UREX extraction

lanthanides from the other fission products. The final extraction operation, TALSPEAK, partitions the lanthanide fission products from the TRU elements.

Off-gases from all processing operations must be treated as necessary to meet emission requirements.

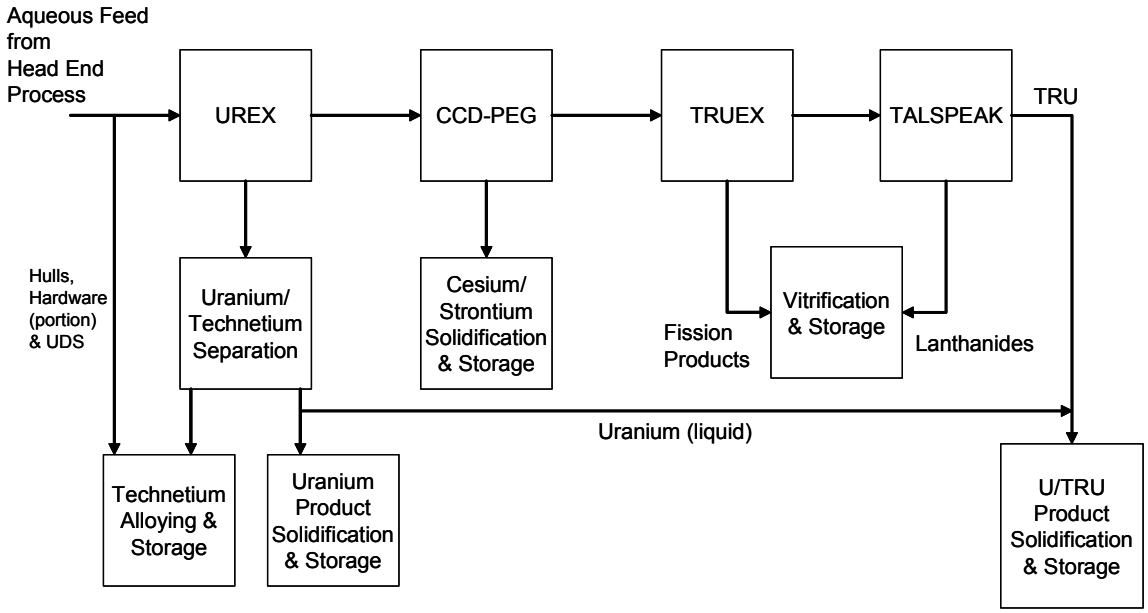

Figure 5 Generic Aqueous Separations Processing Block Flow Diagram

2.3.3.1 Aqueous Separations Process Products

There are two product streams generated by the UREX+1a separations process (Figure 3), a uranium oxide for potential future reuse and a uranium-transuranic (U/TRU) oxide material that will be used to fabricate fuel for the advanced recycling reactors. The individual product streams are concentrated and converted to oxides.

Uranium Solidification

After separation from technetium, a portion of the uranium solution is transferred to U/TRU oxide solidification for blending with the TRU product. The remaining uranium solution is converted to a solid (oxide) and packaged for storage and potential future reuse or disposal as low level waste. Off-gas will be passed through a cleanup system for emission control

U/TRU Oxide Solidification

Purified solutions of actinides (Pu, Np, Am, Cm) from the TALSPEAK process are combined with uranyl nitrate from the UREX process and converted to a stable oxide form and packaged for storage.

The packaged material will be stored until shipped to a fuel fabrication facility for fabrication into fuel for an advanced recycling reactor.

2.3.3.2 Aqueous Separations Waste Processing

There are three main waste streams generated from the UREX process (Figure 5). The streams are technetium (Tc), cesium/strontium (Cs/Sr) and fission products (including lanthanides). The baseline waste form for each stream is different and is discussed below.

Technetium Recovery and Immobilization

Technetium co-extracted with uranium is separated by an ion exchange process. The loaded ion exchange resin is then pyrolyzed to produce a metallic technetium product. The recovered metallic technetium is then alloyed with a portion of the fuel hulls and hardware, and UDS to produce a metallic waste form that will immobilize the technetium. This high level waste form will be packaged for on-site storage awaiting shipment to a geological repository for disposal.

Cs/Sr Solidification

The Cs/Sr solution from CCD-PEG is evaporated and subsequently solidified. The current baseline process is to stabilize the components with additives to produce a solid waste form. Active cooled storage may be required for several years. Upon sufficient decay to reduce radiation and thermal output the Cs/Sr solid waste form will be disposed of in an appropriate facility. Another option for Cs/Sr is for it to be combined with the Fission Product/Lanthanide stream and made into a borosilicate glass.

Fission-Product/Lanthanide Solidification

The fission product waste streams from TRUEX and lanthanides from TALSPEAK separations processes must be treated to a solidified, leach-resistant waste form suitable for disposal in a high level waste geological repository. The final waste form is assumed to be borosilicate glass in a stainless steel waste package[5]. Storage and cooling of the solidified high-level waste (HLW) package will be required prior to shipment to the geologic repository.

2.3.4 SNF Electrochemical Separations

The separation and recovery of uranium and TRU from SNF is completed in the electrochemical processing step. The metal product from the electroreduction process are transferred to a molten salt electrorefiner where a uranium metal product is collected on steel electrodes, and harvested along with entrained salt. The lanthanides and other fission products that do not partition into the electrolytic reduction salt will be converted to chlorides in the electrorefiner salt (Figure 6). The transition metals and hulls remain with the anode in the electrorefiner. The recovered hulls, noble metals, and fission products from the anode are melted into metal ingots for storage and disposal.

[5] This form represents a known approach to achieving a waste package that can be approved by Office of Civilian Radioactive Waste Management (OCRWM) for disposal in the high level waste repository with minimal impact.

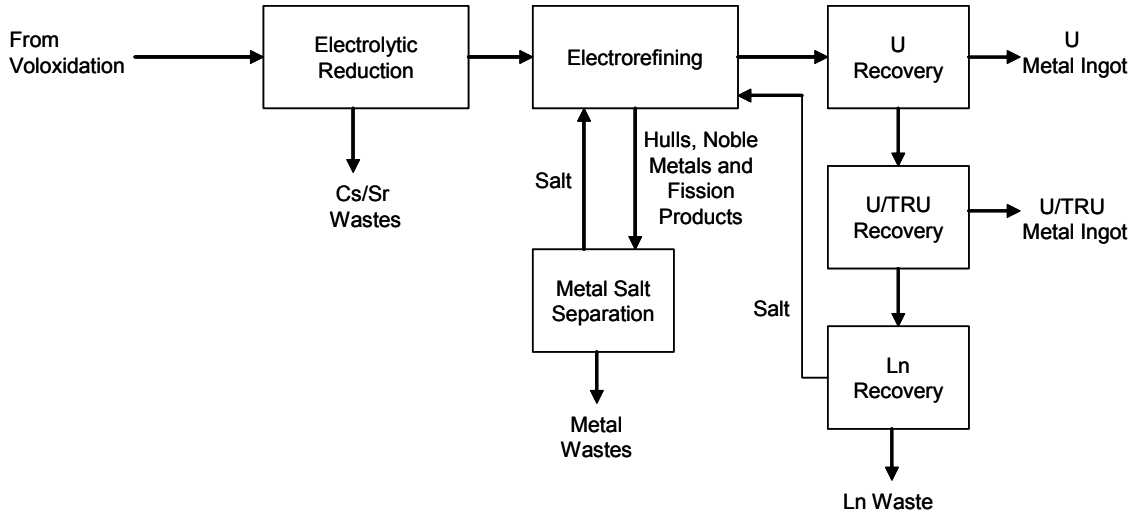

Figure 6 Generic Electrochemical Processing Block Flow Diagram

The uranium and salt mixture is processed to separate the salt and produce a uranium metal ingot. The salt is further process to first remove the TRU elements creating a U/TRU metal ingot and second to remove the lanthanides (Ln). The salts are recycled back to the electrorefiner and the Ln waste is converted to a glass for disposal. The process is shown in Figure 6.

There are two products and three waste streams generated from electrochemical processing of LWR SNF. The two products are a uranium metal and a U/TRU metal. These metals can be converted to oxide and stored or kept in metal form.

The three waste streams are Cs/Sr, metal, and Ln wastes. The Cs/Sr combined with the zeolite will be converted to a glass-like form and stored until it has sufficiently decayed for disposal. The metal wastes will be converted to ingots and packaged for on-site storage awaiting shipment to a geological repository for disposal. The lanthindes will be solidified in a glass matrix, packaged, and stored on-site awaiting shipment to geologic repository.

2.3.5 Process Support for Separations

The LWR recycling facility requires a wide range of process support functions. Process support includes but is not limited to off-gas handling, solvent recovery, and acid recovery. Although not discussed in detail in this section, another important process support function is the make-up of the chemicals needed in the separations process such as the solvent mixtures, various acids, and electrolytic salts. Many of these chemicals will be brought onto the site in large quantities and stored until needed. Electrochemical processing does not require solvent or acid recovery.

Off-Gas Handling
Off-gases (vents) from all process and chemical systems will undergo treatment incorporated into the ventilation system. The process must provide for defense-in-depth (i.e., multiple barriers and/or confinement zones to control releases as close as possible to the source). Volatile off-gas components such as iodine, krypton, carbon-14, ruthenium, and tritium require treatment in order to meet emissions (permit) requirements. Recovered gases will be packaged for disposition.

Solvent Recovery
Spent solvent from solvent extraction operations is sequentially washed to remove radioisotopes and degradation products from the solvent. Washed solvent is re-circulated for process use. Spent solvent will be used in the reduction of NOx to NO. Solvent that cannot be reused or used elsewhere in the facility will be dispositioned per applicable regulatory requirements.

Acid Recovery
Evaporator overheads from all processes are collected for further treatment. Where possible, acid will be recovered and recycled. Recovered acid will be recycled for process makeup where feasible. Acid that cannot be reused will be sent to an onsite industrial wastewater treatment facility for processing.

2.3.6 Waste Management

Waste products may be generated at every step of the separations process operations. Generated wastes will be managed in accordance with applicable Federal, state and local laws, regulations and requirements. A preliminary disposal pathway has been developed for each anticipated waste stream from the recycling facility. Since the time frame for construction and operation of the recycling facility is greater than 10 years, there may be other treatment and/or disposal options available for any of the wastes described in this report.

The wastes generated from the recycling facility will be categorized as either low-level waste (LLW), Greater-Than-Class C (GTCC) wastes, HLW, hazardous waste or non-hazardous waste. The categorization will depend on the radioisotopes present in the waste form, relative concentrations, and in some cases source of the waste regardless of concentration. A brief description of LLW, GTCC and HLW has been provided below. A variety of radioactive waste processing techniques are planned and waste disposal pathways are identified as shown in Figures 7 and 8. The disposal pathways outlined in Figures 7 and 8 are based on current laws, policies and regulations. It is possible for a disposition pathway to be changed if, in the future, a law, policy or regulation is changed.

It is the generators responsibility to properly characterize the waste stream prior to disposition. In general, a generator's characterization approach for each waste stream will consider:

- its source

- its use prior to being declared a waste
- its predominant radionuclide content and distribution
- its physical properties and chemical constituents
- the type of disposal container used
- the feasibility of quantifying a package's radioisotope or chemical content directly or indirectly using emitted radiation

All waste forms will meet applicable waste acceptance criteria for the waste treatment or disposal facility prior to leaving the facility. The primary wastes include activated metals (fuel rod hulls and assembly hardware), sorbed gaseous fission products (tritium, krypton, xenon, ruthenium, iodine and carbon-14), solidified fission products, and solidified processing liquids. Waste such as tritium and krypton with relatively short half-lives will be placed into decay storage prior to disposal.

Low activity liquid radioactive waste is assumed to be treated at an onsite permitted wastewater treatment facility. The facility will discharge to a permitted outfall. All emissions will meet regulatory (permit) limits. All wastes generated within the wastewater facility will be managed accordingly. Solvents and other similar organics are anticipated to be shipped for offsite treatment and disposal. Some of the solvents will be used in the reduction of NOx to NO.

Hazardous wastes will be treated to immobilize or destroy the hazardous component. All hazardous wastes will be treated, managed and stored in accordance with RCRA regulations and shipped to RCRA permitted facilities for treatment, storage, and/or disposal.

Proven technology has been applied as a baseline for all waste treatment processes. No credit was taken for emerging technology improvements. The LWR SNF recycling facility will consider waste minimization and pollution prevention to minimize facility and equipment contamination and to make future decontamination and decommissioning as simple and economical as possible.

2.3.6.1 Low Level Waste Description

LLW are wastes containing source, special nuclear, or byproduct material that are acceptable for disposal in a shallow land disposal facility. For the purposes of this definition, low-level waste has the same meaning as in the Low-Level Waste Policy Act (PL 95–573, December 22, 1980) that is, radioactive waste not classified as high-level radioactive waste, transuranic waste, spent nuclear fuel, or byproduct material as defined in section 11e.(2) of the Atomic Energy Act (AEA) (PL 83-703, August 30, 1954) or naturally occurring radioactive material.

Low level radioactive wastes can be in the form of solids, liquids, or gases. Low level radioactive waste is also classified based upon the concentration and type of radionuclides involved (10 CFR Part 61). LLW are classified in accordance with 10 CFR 61.55.

Wastes that have nuclide concentrations greater than values listed in 10 CFR 61.55 are generally not acceptable for near surface disposal. These wastes are also low level waste but for the purposes of this report are considered as a separate category called GTCC wastes, which is discussed in Section 2.3.6.2.

Low-level wastes include both Resource Conservation Recovery Act (RCRA) (also known as mixed wastes) and non-RCRA regulated radioactive wastes, these waste will be disposed of at NRC licensed LLW disposal facility. Mixed wastes may be treated prior to disposal to destroy or immobilized the hazardous component. The residue from the treatment process will be appropriately packaged and disposed of in accordance with applicable regulations. Liquid waste streams containing radioactive materials will be treated (i.e., solidified) and classified according to the appropriate DOE or NRC waste regulations. Some liquid waste streams may be sent to the onsite industrial wastewater facility for treatment. Solid LLW from process operations, such as equipment, general operations/maintenance waste, and job control waste will be packaged for disposal in accordance with existing regulatory guidelines.

2.3.6.2 Greater Than Class C Waste Description

Greater Than Class C waste is radioactive waste generated by licensees of the U.S. Nuclear Regulatory Commission (NRC) that exceeds the concentration limits of radionuclides established for Class C waste [see Section 2.1 and 10 CFR 61.55(a)(2)]. The NRC issued a final rule requiring the disposal of GTCC low-level radioactive waste in a geologic repository, unless disposal has been approved elsewhere (*54 FR 22578*, codified at 10 CFR Part 61). Although the NRC has indicated that the disposal of GTCC waste in near-surface disposal facilities is generally not acceptable, the requirements of 10 CFR Part 61 would be applicable to the disposal of commercially generated GTCC waste in “intermediate” disposal facilities. The exception to the definition allows NRC to authorize such waste to be disposed without necessarily invoking the additional requirements of 40 CFR Part 191, “Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes”. Disposal of GTCC waste in a near-surface land disposal site requires a performance assessment to be prepared and approval by the NRC for the waste form and disposal location.

In accordance with the Low-Level Radioactive Waste Policy Act, the U.S. Department of Energy (DOE) is responsible for disposal of GTCC wastes; however, disposal of GTCC waste generated by a NRC licensee is to be disposed of in a facility licensed by the NRC. In short, DOE is responsible for siting, constructing, operating and maintaining a GTCC disposal facility and NRC will be the licensing authority.

GTCC waste which will be produced at a recycling facility can be segregated into two categories. The first category would be GTCC waste due to activated metals. The second category is due to other isotopes such as cesium-137, strontium-90, iodine-129, technetium-99, carbon-14 and transuranics (atomic number greater than 92). GTCC

can also be mixed with RCRA hazardous waste, which will make disposal a little more complex.

2.3.6.3 High Level Waste Description

In the *Nuclear Waste Policy Act of 1982*, as amended, the term high-level radioactive waste is defined as: "(a) the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and (b) other highly radioactive material that the Commission, consistent with existing law, determines by rule requires permanent isolation."

Irradiated or spent nuclear fuel is used fuel from a reactor that is no longer efficient in creating electricity, because its fission process has slowed. However, it is still thermally hot, highly radioactive, and potentially harmful. Until a permanent repository for spent nuclear fuel is built, licensees must safely store this fuel at their reactors or other locations licensed for storage. Recycling extracts isotopes from spent fuel that can be used again as reactor fuel. The waste from recycling is highly radioactive and contains fission products and other highly radioactive material, in sufficient concentrations, that is determined, consistent with existing law, to require permanent isolation.

The identification of high-level waste is considered relatively straightforward since it is primarily linked to the source from which it was derived, i.e., it is the highly radioactive material resulting from the reprocessing of spent nuclear fuel. Background and knowledge of both the *Nuclear Waste Policy Act of 1982* definition, as amended, and the NRC definition, in 10 CFR Part 60, is needed to ensure that waste that is to be managed as high-level waste has been properly characterized. Wastes that are produced upstream of the separations processes, from such processes as chemical or mechanical de-cladding, fuel dissolution, cladding separations, conditioning, or accountability measuring, are not high-level waste. Such wastes are considered processing wastes and should be managed as either GTCC, mixed low-level, or low-level waste.

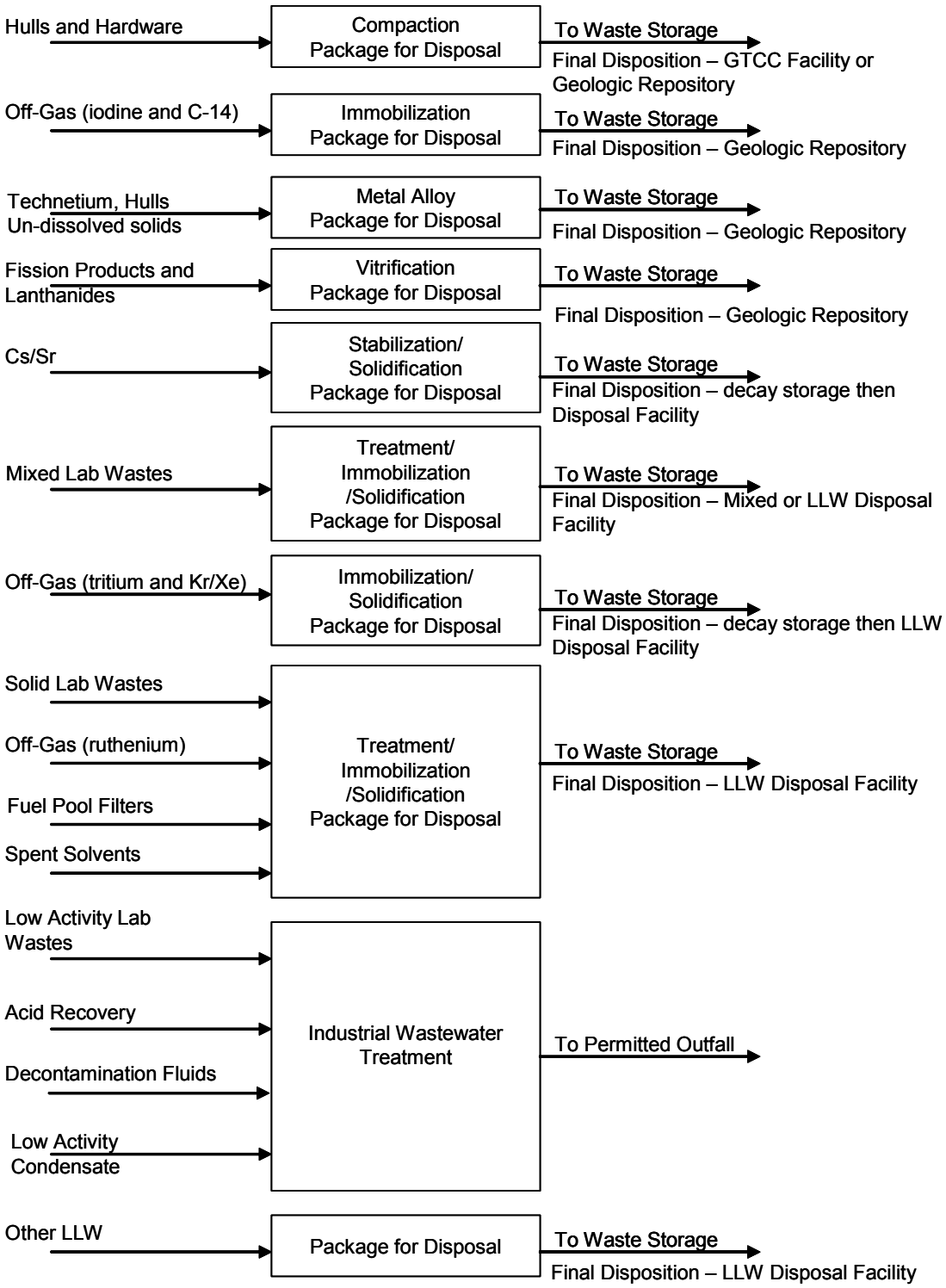

Figure 7 Schematic Block Flow Diagram for Radioactive Waste Management for Aqueous Separations

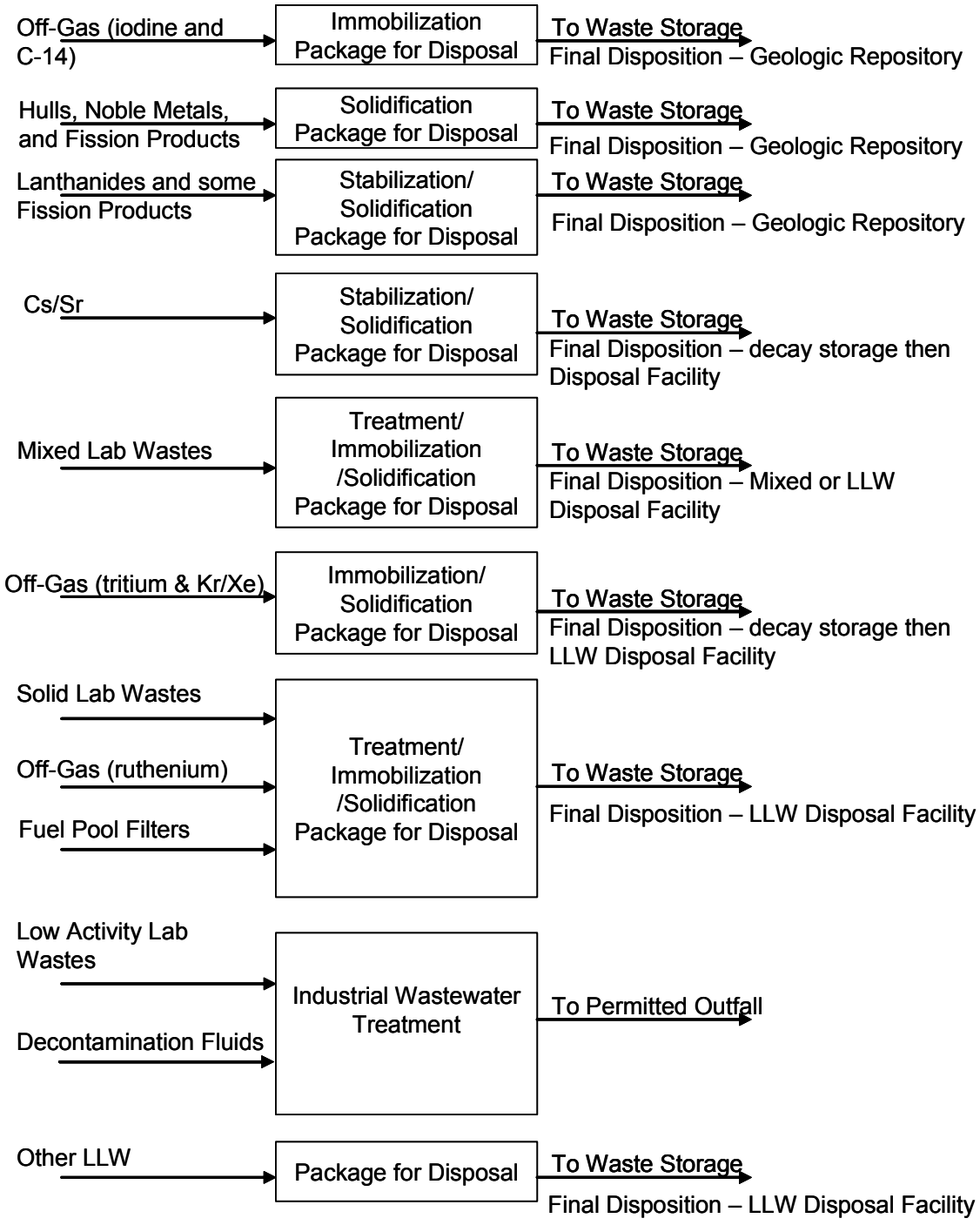

Figure 8 Schematic Block Flow Diagram for Radioactive Waste Management for Electrochemical Processing

2.4 Facility Requirements

The recycling facility includes process buildings and support buildings as shown schematically in Figure 9 for an 800 MTHM/year aqueous separations facility and Figure 10 for a 300 MTHM/year electrochemical processing facility. The specifics for each type of separations facilities are provided in the following sections. Section 3.0 will provide the construction and operational information for an aqueous separations facility and Section 4.0 will provide the construction and operational information for an electrochemical processing facility.

Each of the types of separations facility the site is anticipated to have, at a minimum, the following buildings, support structures and features:

- Main Process Buildings
- Support Facilities – Mock-up testing, etc.
- Administrative Buildings
- Truck Loading Docks
- Analytical Support Facility
- Fire Protection Facility and Tanks
- Entry Control Facilities (ECFs)
- Emergency/Standby Diesel Generator Buildings
- Cooling Towers
- Chillers, Chemical Feed and Chilled Water Pump Buildings
- Electrical Power Substations
- Equipment Maintenance Facilities
- Nitrogen/Argon Storage Tanks
- Chemical Storage Tanks
- Spare Equipment Laydown Yard
- HVAC Exhaust Stacks
- Waste Handling Facilities
- Commodities Warehouse
- Roads and Parking Areas
- Runoff Detention Basins
- Railroad Tracks
- Sanitary Wastewater Treatment Facility
- Industrial Wastewater Treatment Facility
- Instrument Maintenance and Calibration Shops
- Communication System Buildings

2.4.1 Analytical Laboratory

Fully-equipped analytical laboratories are provided to enable rapid chemical, isotopic, and physical property analyses required to support process control, accountability, criticality safety, and waste management needs. Wastes from analytical laboratories will be appropriately segregated, characterized, and incorporated into recycle or waste streams.

2.4.2 Security

It is anticipated that the main process facilities would be located within an enhanced security area to protect the nuclear material from diversion or sabotage. Entry control facilities at the entrance to the security protection areas would allow security personnel to inspect all vehicles and all personnel entering and leaving the LWR SNF recycling facility. Physical security would be provided by armed guards.

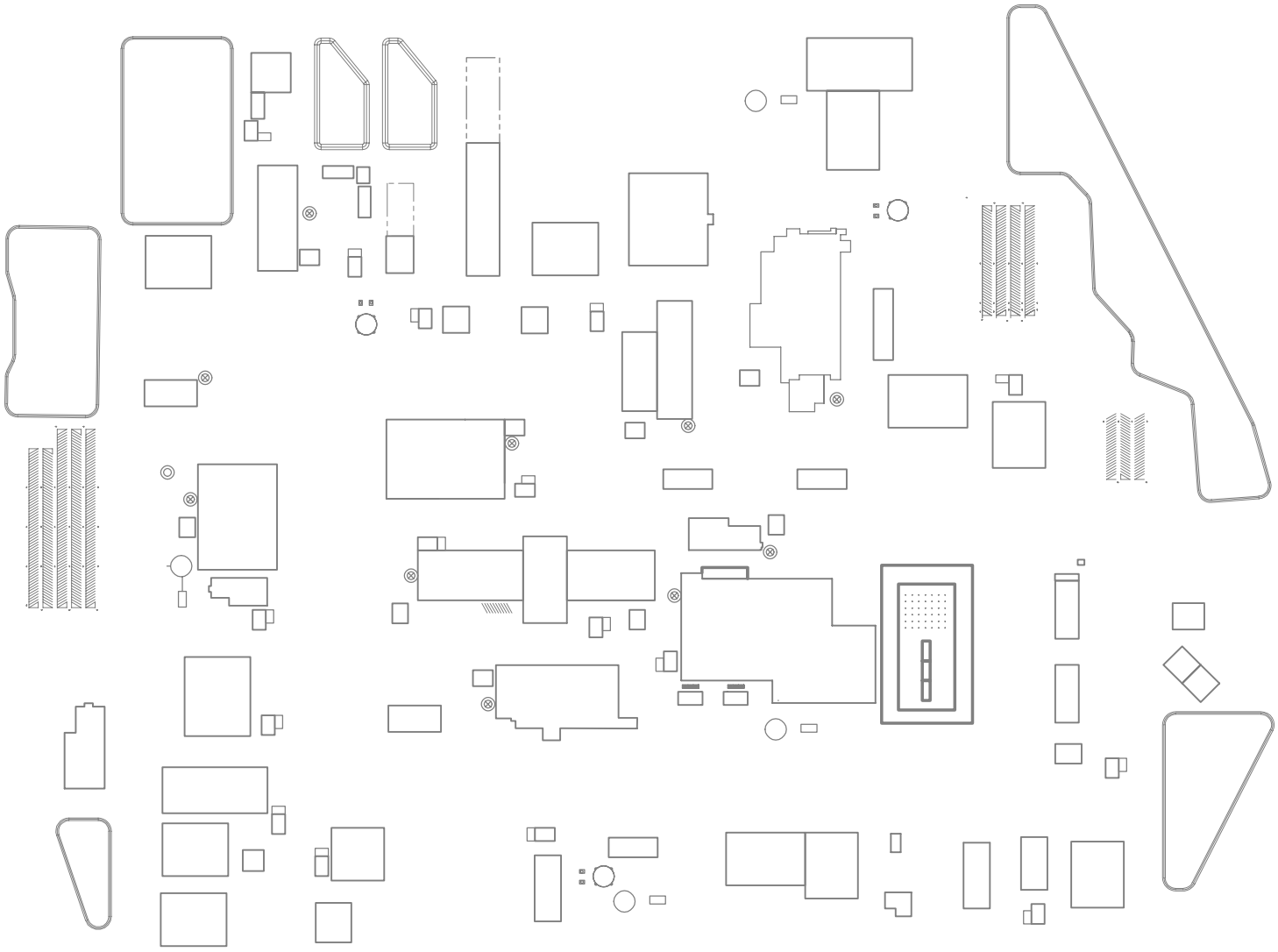

Figure 9 Conceptual Aqueous Recycling Facility Layout

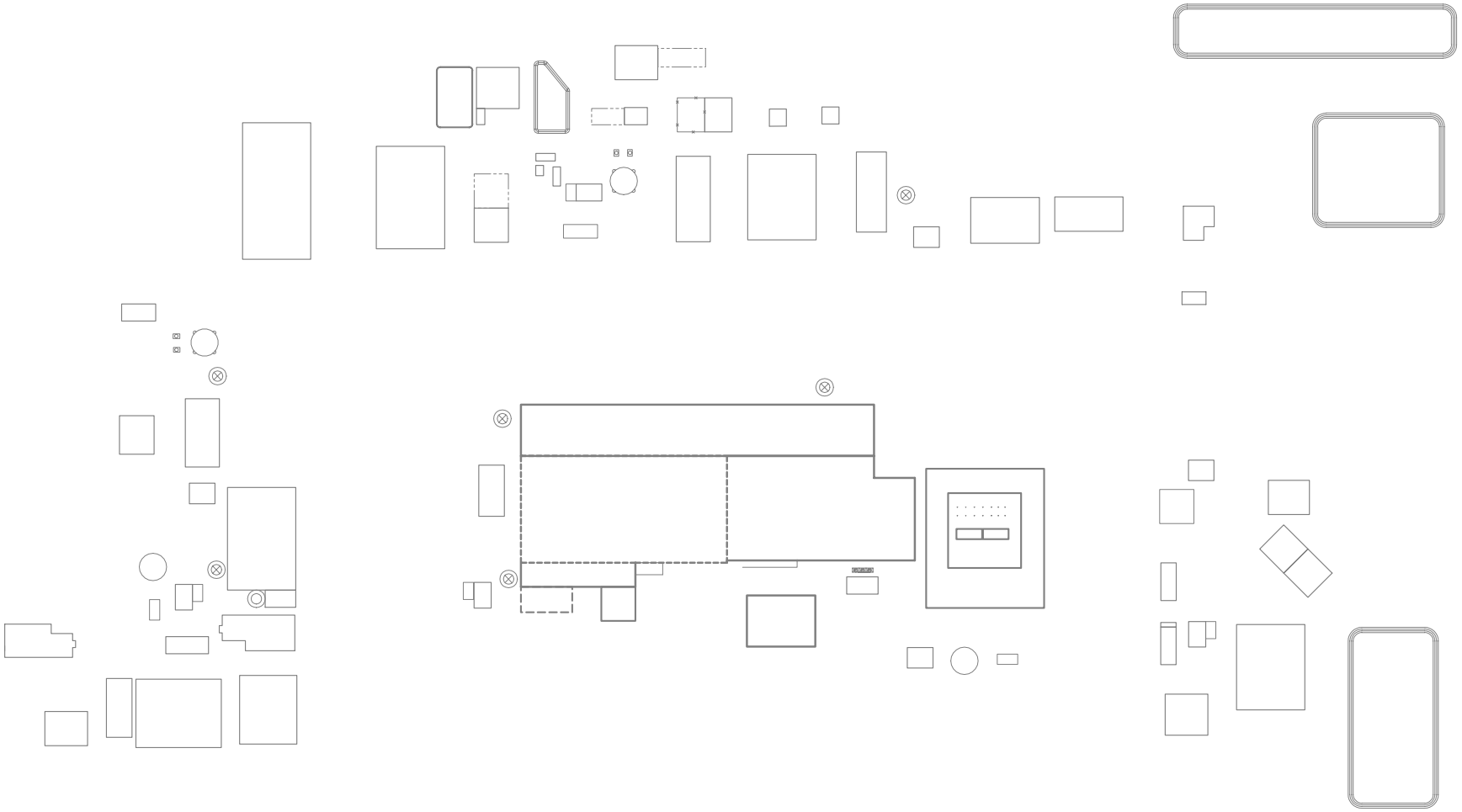

Figure 10 Conceptual Electrochemical Processing Recycling Facility Layout

3.0 Construction and Operational Data for Aqueous Separations Facility

This section provides the facility requirements, construction and operational information for an aqueous separations facility. The information is based on a UREX+1a separations process.

3.1 Aqueous Separations Facility Requirements

The recycling facility includes process buildings and support buildings as shown schematically in Figure 9 for an 800 MTHM/year aqueous separations facility. The total site area within a property protection fence is on the order of 500 acres for the upper bounding 800 MTHM per year facility. It is assumed that the 100 MTHM per year facility layout would be similar but less total acreage. The layout for the two existing DOE facilities would depend on the facility chosen and overall DOE site layout. The support facilities required for the two existing DOE facilities would be similar to the Greenfield facilities but potentially more spread out due to existing structures, etc. The support facilities for the two existing DOE facility would be shared with the entire DOE site and may require upgrades to accommodate processing needs.

3.1.1 Process Buildings

The proposed concept would place the processes into as few buildings as possible. The major process functions regardless of recycling process are:

- receiving, storing, and head-end preparation of SNF;
- processing, recovering, and purifying spent nuclear fuel;
- solidification and storing of Uranium and U/TRU product;
- solidification and storing of fission products and other wastes; and
- solidification and storing of Cs/Sr wastes.

With the exception of uranium process, all of these process functions require shielding provided by hot cells and/or canyons. The process buildings would generally be multi-storied, reinforced concrete structures, with hot cell facilities below grade and equipment handling above grade. The process buildings are hardened to meet safety and security requirements. Containment, confinement, shielding and criticality control measures are integrated in the facility design and layout to provide personnel protection and environmental protection from exposure to radioactive and hazardous substances.

The footprint for the processing areas is estimated to be on the order of 1,040,467 ft^2 for the 800 MTHM facility. The process area footprint provides space for processing area support functions including mechanical, electrical, and process control equipment, analytical laboratory spaces; cold storage; and access corridors. In the current concept, the shielded areas are placed below grade (to depths approaching 40 feet), and the overhead cranes and other support equipment required for unloading and moving shipping casks and processing equipment extend to heights averaging 70 feet above grade. Some buildings may require building heights greater than 70 feet above grade.

The process areas also include various tunnels for the transfer of materials between buildings.

Construction estimates (concrete, aggregate, water, structural steel, etc.) presented in this report are based on this bounding footprint. Table 5 provides the footprint area discussed above for the aqueous recycling facility size alternatives. A portion of support buildings for an existing DOE facility may not be co-located with the processing facilities, especially if they are shared resources used by the entire DOE site. The area needed by the two existing facilities is anticipated to be the same as area needed for the Greenfield 100 MTHM/year facility

Table 5 Aqueous Separations Building Size Details

	Area (ft^2)		
	100 MTHM/year Greenfield Facility	**800 MTHM/year Facility**	**Existing DOE Facilities[1]**
Total Area of Main Processing Buildings	520,250	1,040,467	520,250
Total Support Building Area	1,140,228	2,280,456	1,140,228
Total Building Area	1,660,478	3,320,923	1,660,478

1 – Anticipated to be bounded by the estimates for the 100 MTHM/year Facility for both F-Canyon and FPR. The same amount of space is needed regardless of location.

The current footprint for the 800 MTHM/year LWR SNF Recycling Facility assumes only one year of storage for each of the types of waste. To account for the potential for additional storage capacity, the footprint for the LWR SNF Recycling Facility would need to be increased by the following values depending on waste stream. It is expected, however, that a disposal pathway for these wastes will be available while the facility is operating. If so, additional storage capacity would not be required. A phased construction plan with expandable capacity is envisioned to handle this waste and provide sufficient but not excess storage capacity. New capacity would be built every five to ten years to accommodate a portion of the total waste that would be generated during the subsequent years of production. The need for the construction of new storage space would be reduced or eliminated when disposal paths for the various waste categories are decided.

- 3,260 ft^2/yr for HLW storage (includes hulls and hardware*)
- 8,150 ft^2/yr for Cs/Sr waste storage
- 13,600 ft^2/yr for GTCC waste storage
- 111,260 ft^2/yr for LLW storage (includes any grouted LLW)
- 2,300 ft^2/yr for combined Hazardous Waste/Mixed Waste storage

* Hulls and Hardware are GTCC waste but due to the need for remote handling they are assumed be placed in the same storage facility as the HLW to reduce the need for two storage facilities with remote handling capabilities.

UREX+1a aqueous separations process is one of several separations processes that can be utilized for LWR SNF (see Section 6.0). If another method of aqueous separations was chosen, the size of the facility would change. For example, if a co-extraction process was used, all the different waste streams from the process such as fission products, lanthanides, etc could be combined into one waste form. Storage of one type of waste would require less footprint space than the storage of several different waste forms. Overall, a co-extraction facility would be approximately 25% smaller than an UREX+1a facility. The estimated total building area of an 800 MTHM/year co-extraction based separations facility is approximately 2,543,665 ft^2 (Reference 11). Additional HLW storage capacity would increase the footprint approximately 38,600 ft^2 every 5 years.

3.1.2 Support Buildings

The major support buildings and structures include, but not limited to, one or more utility/mechanical buildings, storage areas for rail- or trailer-mounted shipping casks, one or more exhaust stacks, one or more fan houses, and reagent storage areas. Other support buildings and structures include two temporary concrete batch plants (approximately 36 acres), temporary construction support facilities, and temporary construction laydown areas (approximately 240 acres) that would be required only during the construction phase. Permanent structures include, but are not limited to, waste handling facilities (LLW, mixed waste, and hazardous waste), analytical laboratory, a radiological laundry, maintenance/machine shop, a cold test facility, a mock-up and training facility, a steam plant, administration buildings, security support facilities, bulk chemical storage, a warehouse, an emergency response/fire facility, personnel access points, a domestic water treatment plant, a sewage treatment facility, radioactive industrial wastewater treatment facility, electrical substations, stormwater retention areas, and parking areas. The total footprint of support structures is estimated to be 2,280,456 ft^2 for the 800 MTHM/year facility. Table 5 provides the area information for the three alternatives being evaluated for aqueous separations.

Support structures such as laundry, steam plant and sanitary wastewater treatment plant will have solid and/or liquid effluents. The laundry effluent could include radionuclides or hazardous constituents, and therefore, the effluent from this facility will be transferred to the radioactive industrial wastewater treatment facility. Effluents from the steam plant and sanitary wastewater treatment plant are not expected to contain hazardous or radioactive material, and therefore, these effluents will be appropriately treated and discharged to permitted outfalls.

3.1.3 Aqueous Separations Construction Requirements and Impacts

The construction of the 800 MTHM/year facility is estimated to occur over a 13 year period. Construction materials, utilities and wastes are summarized in Tables 6 and 7. The construction materials are estimated based on an estimated facility footprint provided in Table 5. Fuel requirements are primarily based on estimates of the machinery and operating requirements for excavation of the processing building areas and do not include other site preparation (e.g. grading). For the purpose of estimating the air quality impact of construction, it should be assumed that at a minimum the entire

site maximum area of 500 acres, less for 100 MTHM/year facilities, will be disturbed by grading or other site preparation activities. Additional acreage outside of the site's 500 acres will be disturbed in support of construction activities as presented in Table 7. Estimates of these impacts, in addition to spoil piles, etc., should be added to the excavation impacts presented in Table 7. Water requirements include water for dust suppression, concrete production, and washdown. Aggregate volume does not include the aggregate used in concrete; it is only aggregate used for other purposes such as road base. The concrete estimate includes the aggregate used for the making of concrete. Structural steel includes reinforced steel embedded in concrete in addition to all other structural steel required.

The construction impacts for an existing DOE facility will be slightly different than for the 100 MTHM/year Greenfield facility. The construction activities will consist of the following, 1) removal of unnecessary equipment and piping; 2) modifications to add new equipment and piping; and 3) infrastructure upgrades such as security, electrical power, cranes, water, etc. A few new facilities, such as dry fuel storage and Cs/Sr decay storage, may need to be constructed in support of recycling facility, depending on which existing DOE facility is chosen. The waste generation will also vary from a Greenfield site. Low level and mixed waste may be generated during facility modifications especially at the F-Canyon Facility. The facility was used for 50 years in support of DOE missions and areas that would require modification and demolition are radiological areas. In addition, there is a possibility to generate contaminated soil in areas that have been previously used for industrial purposes.

Table 6 Aqueous Separations Construction Requirements

Material / Resources	Consumption/ Use 100 MTHM/year Greenfield Facility	Consumption/ Use 800 MTHM/year Facility	Consumption/ Use F-Canyon**	Consumption/ Use FPR**
Peak Electrical Energy (Million Volt Amps (MVA))				
Total	58	82	17	29
Peak Yearly	54	77	16	27
Diesel Generators	Yes – Portable	Yes – Portable	Yes – Portable	Yes – Portable
Number of horsepower-hours of diesel-fueled engines (bulldozers, dump trucks, diesel generators, etc) during the peak year of construction	1,074,297	1,534,710	214,849	429,719
Number of delivery vehicles during peak year of construction	24,500	35,000	7,350	12,250
Concrete (yd^3)				
Total	1,155,000	1,650,000	231,000	462,000
Peak Yearly	140,000	200,000	28,000	56,000
Structural Backfill (yd^3)				
Total	4,480,000	6,400,000	896,000	1,792,000
Peak Yearly	1,400,000	2,000,000	280,000	560,000
Aggregate (yd^3)				
Total	700,000	1,000,000	140,000	280,000
Peak Yearly	210,000	300,000	42,000	84,000
Structural Steel (tons)				
Total	210,000	300,000	63,000	105,000
Peak Yearly	35,000	50,000	10,500	17,500
Liquid fuel and lube oil (gal)				
Total	12,670,000	18,100,000	2,534,000	5,068,000
Peak Yearly	1,680,000	2,400,000	336,000	672,000
Gases (m^3) – i.e. welding gases, etc.				
Total	732,800	1,046,855	219,840	366,400
Peak Yearly	98,850	141,212	29,655	49,425
Water (gal)				
Total	53,200,000	76,000,000	15,960,000	26,600,000
Peak Yearly	8,400,000	12,000,000	2,520,000	4,200,000
Land (acre)				
Laydown Area Size	216	240	22	43
Temporary Support Facilities	130	110	Not Applicable	Not Applicable
Parking Lots	54	60	5	11
Number of Temporary Concrete Batch Plants	1	2	1	1
Temporary Concrete Batch Plant Area	32	36	32	32
Post Construction Developed Area	300	500	300	300

Material / Resources	Consumption/ Use 100 MTHM/year Greenfield Facility	Consumption/ Use 800 MTHM/year Facility	Consumption/ Use F-Canyon	Consumption/ Use FPR
Employment During Construction				
Construction period (years)	11	13	6	7
Total employment (worker years)	41,744	55,659	8,349	16,698
Peak employment (workers)	10,965	12,183	2,193	4,386

* - Expected to be the same or less than a 100 MTHM/year Greenfield facility
** - F-Canyon was estimated to be 70 to 80% less than the Greenfield alternative and FPR was estimated to be 50 to 60% less than the Greenfield alternative

Table 7 Aqueous Separations Construction Wastes

Waste Generated During Construction	Volume 100 MTHM/year Greenfield Facility	Volume 800 MTHM/year Facility	Volume F-Canyon	Volume FPR
Hazardous				
Liquid (gal)	37,800	54,000	7,560	15,120
Solid (yd^3)	95	135	19	38
Nonhazardous (Sanitary)				
Liquid (gal)	410,900,000	587,000,000	82,180,000	164,360,000
Solid (yd^3)	132,300	189,000	26,460	52,920
Nonhazardous				
Liquid (gal)	2,520,000	3,600,000	504,000	1,008,000
Debris from Site Clearing	15,400 tons	22,000 tons	3,080 tons	6,160 tons
Excavated Material	4,480,000 yd^3	6,400,000 yd^3	896,000 yd^3	1,792,000 yd^3
Metal Scrap	31,500 tons	45,000 tons	6,300 tons	12,600 tons
Dunnage	5,600 yd^3	8,000 yd^3	1,120 yd^3	2,240 yd^3
Low Level				
Liquid (gal)	Not Expected	Not Expected	10,000	1,000
Solid (ft^3)	Not Expected	Not Expected	50,000	5,000
Mixed Low-level				
Liquid (gal)	Not Expected	Not Expected	500	50
Solid (ft^3)	Not Expected	Not Expected	5,000	500

3.1.4 Aqueous Separations Operations Materials and Wastes

During normal operations, the LWR SNF recycling facility will process SNF to produce uranium and transuranic products and waste materials. Throughputs and inventories of these processing materials, shown in Tables 8 and 9, are based on the conceptual process flow sheets that are currently under development. In addition to the processing wastes identified in Tables 8 and 9, the facility will produce hazardous, sanitary, and other non-hazardous wastes. Estimates of all the operations wastes, including process

wastes, are provided in Table 10. Estimates of the operations data are provided in Table 11. Additional information on parameters for Operations is provided in Section 3.2.

Sanitary wastes generated by the sanitary wastewater treatment plant include both liquid and solid effluents. Liquid effluents from the treatment could be used on site for landscape watering, and process water, and any excess liquids would be discharged to a permitted outfall or evaporation pond. Treated solids would be disposed offsite in an appropriate disposal facility. Radioactive wastes from support facilities such as the analytical laboratory, laundry, storage facilities, etc. would be treated at the radioactive industrial wastewater treatment facility. The liquid effluents from this facility would be discharged to an outfall and the solids would be disposed offsite in an appropriate facility such as a low-level waste disposal facility. Wastes from the machine and maintenance shops would be the same as wastes from similar commercial facilities, and these wastes would be handled in a manner equivalent to these commercial facilities. Other non-hazardous wastes generated at the site include office and cafeteria wastes which will be packaged for disposal at commercial landfills.

Table 8 Estimates of Fuel Processing Materials and Wastes from Aqueous Separation Operations 100 MTHM/year Facilities (Greenfield, F-Canyon and FPR)

Feed/Product/ Waste	Daily Rate (kg/day)	Annual Rate (kg)	Annual Bulk Container Rate	Maximum Storage Duration (years)
LWR Fuel Feed (fuel portion only)	1,131	113,073	228 assemblies	2
U Solidification and Storage Product	1,068	106,847	267 55-gallon drums	1
U/TRU Solidification and Storage Product	54.9	5,490	384 cans[1]	1
Fuel Hardware and Hulls Waste	412.2	41,218	12 canisters[2]	1
Tc metal alloy Waste Form	23.8	2,380	1 canisters[2]	1
Cs/Sr Waste Form	94.1	9,408	510 canisters[3]	1
FP/Lanthanide Vitrified Waste Form	386	38,649	13 canisters[4]	1

1 - Can holds 14.3 kg of material
2 - Canister holds 3,600 kg of material
3 - Canister holds 18.45 kg of material
4 - Canister holds 2,900 kg of material

Table 9 Estimates of Fuel Processing Materials and Wastes from Aqueous Separations Operations 800 MTHM/year Facility

Feed/Product/ Waste	Daily Rate (kg/day)	Annual Rate (kg)	Annual Bulk Container Rate	Maximum Storage Duration (years)
LWR Fuel Feed (fuel portion only)	3,766	903,850	1,820 assemblies	2
U Solidification and Storage Product	3,558	853,920	2,135 55-gallon drums	1
U/TRU Solidification and Storage Product	183	43,872	3,068 cans[1]	1
Fuel Hardware and Hulls Waste	1,372	329,410	92 canisters[2]	1
Tc metal alloy Waste Form	79.3	19,022	6 canisters[2]	1
Cs/Sr Waste Form	313	75,185	4,075 canisters[3]	1
FP/Lanthanide Vitrified Waste Form	1,287	308,880	106 canisters[4]	1

1 - Can holds 14.3 kg of material
2 - Canister holds 3,600 kg of material
3 - Canister holds 18.45 kg of material
4 - Canister holds 2,900 kg of material

Radioactive wastes from operations will generally fall into three categories: HLW, LLW and GTCC wastes as mentioned in Section 2.3.6. HLW results from reprocessing (also known as recycling) spent nuclear fuel[6] as discussed in Section 2.3.6.3. However, not all waste from a reprocessing facility is considered HLW. All other radioactive wastes not classified as HLW will be either LLW or GTCC wastes.

Estimates of radioactive waste are based on the mass balance calculations performed on the process flows. The radioactive wastes generated at the facility are tentatively classified based on the expected half-lives or curie content and currently laws, policies and regulations. The results are shown in Table 10.

[6] HLW is defined in Nuclear Waste Policy Act of 1982

Table 10 Estimates of Wastes from Aqueous Separations Operations

Waste Category	Volume 100 MTHM/year Facility (Greenfield, F-Canyon and FPR)		Volume 800 MTHM/year Facility	
	Daily	Annual	Daily	Annual
Low Level				
Liquid (L)	2.74	274	8.98	2,156
Solid (m^3)	40.4	4,043	33.1	7,936
Mixed Low-level				
Solid (m^3)	0.11	11	0.46	32
Greater Than Class C (GTCC)				
Solid (m^3)	7.07	707	5.21	1,250
Mixed Solid (m^3)	0.10	10	0.32	77
HLW				
Solid (m^3)	0.28	28	0.92	221
Hazardous				
Liquid (L)	0.70	70	0.42	100
Solid (m^3)	0.32	32	0.39	93
Nonhazardous				
Liquid (L)	495,900	181,000,000*	679,500	248,000,000*
Solid (m^3)	31.0	11,328*	45.1	16,463*

* Waste volumes are based on 365 days per year since facility will be staffed year round and nonhazardous waste generation is based more on number of personnel and facility occupation than number of processing days.

Operation of fuel cycle facilities generates several different types of waste. Some are closely related to the process and throughput (e.g. fission products, used solvents, product packages and containers, and excess acid). Other waste streams (secondary wastes) are more closely related to staffing (e.g. sanitary waste) or plant systems and facilities (filters, laboratory wastes, decontamination material). However, the largest source of secondary radioactive waste is typically associated with routine operation and maintenance of the nuclear facilities and equipment. For NEPA purposes, estimates of total waste were derived by combining "process-related" wastes directly related to throughput, with estimates of secondary waste made for each facility. Estimates of secondary wastes considered process conditions, personnel activities (entries into contamination areas and protective clothing requirements), and forecasts of equipment failures, repairs, and replacement. Detailed estimates considering forecasts of routine operations and both major and minor maintenance activities were prepared for each case. Since the total quantity of waste for any given case is impacted by all of these factors, and their relative contribution varies with the type of operation and source materials, comparisons between cases are unlikely to be directly proportional to throughput except for process wastes. Detailed estimating methodology and facility specific assumptions are described in the *Waste Generation Forecast and Characterization Study - 800 MT/year UREX+1a* (Reference 12).

It is expected that any mixed (hazardous and radioactive) waste containing organic solvents as the hazardous component would be treated to remove that hazardous component. Such treatment would require a RCRA Part B permit to ensure that the hazardous components are treated and the waste is no longer considered RCRA hazardous or acceptable for land disposal per RCRA.

Storage of radioactive wastes would be designed to accommodate shielding, security, heat loading, inventory, storage duration, and other requirements. Packaging of radioactive wastes will be in accordance with applicable DOE, NRC, and/or Department of Transportation (DOT) regulations.

Table 11 Summary of Aqueous Separations Operations Data

Data Required	Consumption/Use 100 MTHM/year Facility (Greenfield, F-Canyon and FPR)	Consumption/Use 800 MTHM/year Facility
Electrical Consumption – daily and annual	3.0 GWh 906 GWh	6.0 GWh 1,440 GWh
Peak electrical demand (MVA) – daily	195	390
Diesel Fuel usage (gal) – annual	121,750	243,500
Other Process Gas (N, Ar, etc) – daily and annual	4,689 scf/day 1,125,440 scf/year	14,068 scf/day 3,376,320 scf/year
Domestic Water (gal) – daily and annual	135,000 40,770,000	175,000 42,000,000
Process Water (gal) – daily and annual	120,000 36,240,000	360,000 108,720,000
Cooling Tower Makeup (gal) – daily and annual	249,600 59,904,000	748,800 179,712,000
Steam (gal) – daily and annual	307,200 73,728,000	921,600 221,184,000
Employment (total workers)	2,500	2,970*
Number of Radiological Workers	1,070	1,657*
Average annual dose to Radiological workers (mrem)	250	250
Maximum annual Radiological worker dose (mrem)	1000	1000

* Additional studies have shown this number to be closer to 3,100 for the total number of workers needed for an 800 MTHM/year facility (Reference 12). The number of required Radiological Workers was also shown to be higher at 2,226. However, it was assumed that only 70% of those Radiological Workers would be qualified to go into the higher radiation areas.

3.2 Summary of Effluents, Emissions and Reagents during Aqueous Separations Operations

This section provides a summary of the effluents, reagents, emissions, etc. that are generated and/or used during operation of a LWR SNF aqueous recycling facility. A summary of nuclear materials and products is provided in Tables 8 and 9. A summary of the wastes from LWR SNF aqueous recycling is provided in Table 10. There are two sources of liquid effluents from the recycling facility, the annual flow rates are shown in Table 12.

Air emissions from the various operations are shown in Tables 13 through 18. The radioactive emissions shown in Table 19 include emissions from the head end processes such as tritium, C-14, I-129, and Ru-106, and the Cs-137 and Ru-106 released from the fission products vitrification process.

Table 12 Liquid Effluents from Aqueous Separations Operations

Effluent	Source	Annual Flow Rate (L) 100 MTHM/year Facility (Greenfield, F-Canyon and FPR)	Annual Flow Rate (L) 800 MTHM/year Facility
Process wastes		No net flow of process liquid wastes	No net flow of process liquid wastes
Liquid Effluent from Industrial Wastewater Treatment Facility*	Cleaning, evaporator condensate, laundry effluent, etc.	2,800,000	21,900,000
Liquid Effluent from Sanitary Wastewater Treatment Facility		173,400,000	206,000,000

* It is anticipated that a portion of this effluent stream will be recycled back to the process to be used as process water.

Table 13 Air Emissions from Extraction and Fuel Buildings

Emissions	100 MTHM/year Facility (Greenfield, F-Canyon and FPR[1])		800 MTHM/year Facility	
	Daily (kg/day)	Annual (kg)	Daily (kg/day)	Annual (kg)
Nitrogen Oxides	0.46	46	1.54	370
Hydrochloric Acid	0.192	19.2	0.64	154
Hydrofluoric Acid	0.192	19.2	0.64	154
Volatile Organics (contributes to Ozone)		<40		<40
Radionuclides	See Table 19			

1 – Assumes that any existing DOE facility would be bounded by the 100 MTHM/year Facility scenario.

Table 14 Air Emissions from U/TRU Solidification Building

Emissions	100 MTHM/year Facility (Greenfield, F-Canyon and FPR[1])		800 MTHM/year Facility	
	Daily (kg/day)	Annual (kg)	Daily (kg/day)	Annual (kg)
Carbon Dioxide (CO_2)	2,162	21,622	7,200	1,728,000
Nitrogen Oxides	0.90	90.1	3.0	720

1 – Assumes that any existing DOE facility would be bounded by the 100 MTHM/year Facility scenario.

Table 15 Air Emissions from Fission Product Solidification Building

Emissions	100 MTHM/year Facility (Greenfield, F-Canyon and FPR[1])		800 MTHM/year Facility	
	Daily (kg/day)	Annual (kg)	Daily (kg/day)	Annual (kg)
Carbon Dioxide (CO_2)	216	21,622	720	172,800
Nitrogen Oxides	0.48	48	1.6	384
Sulfur Oxides	0.192	19.2	0.64	154
Radionuclides	See Table 19			

1 – Assumes that any existing DOE facility would be bounded by the 100 MTHM/year Facility scenario.

Table 16 Air Emissions from Cs/Sr Solidification Building

Emissions	100 MTHM/year Facility (Greenfield, F-Canyon and FPR[1])		800 MTHM/year Facility	
	Daily (kg/day)	Annual (kg)	Daily (kg/day)	Annual (kg)
Carbon Monoxide (CO)	0.192	19.2	0.64	154
Carbon Dioxide (CO_2)	2,688	268,769	8,950	2,148,000
Sulfur Oxides	0.192	19.2	0.64	154
Hydrochloric Acid	0.192	19.2	0.64	154
Hydrofluoric Acid	0.192	19.2	0.64	154

1 – Assumes that any existing DOE facility would be bounded by the 100 MTHM/year Facility scenario.

Table 17 Air Emissions from U/Tc Separation and U Solidification Buildings

Emissions	100 MTHM/year Facility (Greenfield, F-Canyon and FPR[1])		800 MTHM/year Facility	
	Daily (kg/day)	Annual (kg)	Daily (kg/day)	Annual (kg)
Carbon Dioxide (CO_2)	685	68,468	2,280	547,200
Nitrogen Oxides (NOx)	8.11	811	27	6,480

1 – Assumes that any existing DOE facility would be bounded by the 100 MTHM/year Facility scenario.

Table 18 Air Emissions from Analytical Laboratory from Aqueous Separations

Emissions	100 MTHM/year Facility (Greenfield, F-Canyon and FPR[1])	800 MTHM/year Facility
	Annual	Annual
Radionuclides[2]	<10 mrem/year	<10 mrem/year

1 – Assumes that any existing DOE facility would be bounded by the 100 MTHM/year Facility scenario.
2 – Radionuclides are the only expected permitted emissions from the laboratory. All other emissions would be considered insignificant emission under Federal regulations since the emissions are from laboratory used for process quality and control sampling and analysis.

Table 19 Radioactive Air Emissions from Aqueous Separations

Emissions	100 MTHM/year Facility (Greenfield, F-Canyon and FPR[1])		800 MTHM/year Facility	
	Daily (Ci/day)	Annual (Ci)	Daily (Ci/day)	Annual (Ci)
Tritium (H-3)*	9.53	953	31.7	7,619
Carbon -14 (C-14)*	0.022	2.20	0.072	17.34
Krypton-85 (Kr-85)*	238	23,800	792	190,042
Iodine-129 (I-129)*	7.38E-05	0.007	2.44E-04	0.058
Ruthenium-106 (Ru-106)	0.002* 1.52E-08**	0.24* 1.52E-06**	0.0081* 1.90E-07**	1.95* 4.57E-05++
Cesium-137** (Cs-137)	7.08E-10	7.08E-08	2.36E-09	5.66E-07

1 – Assumes that any existing DOE facility would be bounded by the 100 MTHM/year Facility scenario.
* - Emissions from Extraction and Fuel Buildings
** - Emission from Fission Products Building

Table 20 Reagents Used in Aqueous Separations Operations

Reagent
Nitric Acid
Tributyl phosphate
Acetohydroxamic acid (AHA)
n-dodecane
Chlorinated cobalt dicarbollide (CCD) in FS-13
polyethylene glycol (PEG-400)
Phenyltrifluoromethyl Sulfone (FS-13)
Diethylenetramine pentaacetic acid (DTPA)
Guanidinium carbonate
Octyl-(phenyl)-N,N'-diisobutylcarbamoylmethylphosphein oxide (CMPO)
Oxalic acid
Lactic acid
Hydrofluoric Acid
Bis-(2-ethylhexyl)phosphoric acid (HDEHP)
Sodium Carbonate Na_2CO_3
Ceric Acid
Ammonium carbonate
Compressed argon
Compressed nitrogen
Compressed propane
Hydrogen peroxide
Sodium hydroxide
Sodium nitrate
Aluminum nitrate
Lithium nitrate
Sucrose, white granulated
Alkali Borosilicate Glass Frit
Reilex Resin
Activated Carbon
IX Resin

4.0 Construction and Operational Data for Electrochemical Processing Separations Facility

This section will provide the facility requirements, construction and operational information for electrochemical processing facility.

4.1 Electrochemical Processing Facility Requirements

The recycling facility includes process buildings and support buildings as shown schematically in Figure 10 for a 300 MTHM/year electrochemical processing facility. The total site area within a property protection fence is on the order of 250 acres for the 300 MTHM per year facility.

4.1.1 Process Buildings

The proposed concept would place the processes into as few buildings as possible. The major process functions regardless of recycling process are:

- Receiving, storing, and head-end preparation of SNF;
- processing, recovering, and purifying spent nuclear fuel;
- storing of uranium and U/TRU product;
- solidification and storing of wastes.

All of these process functions require shielding provided by hot cells and/or canyons. The proposed process areas could be separated into different buildings or contained within a single, large building. The process buildings would generally be multi-storied, reinforced concrete structures, with hot cell facilities below grade and equipment handling above grade. The process buildings are hardened to meet safety and security requirements. Containment, confinement, shielding and criticality control measures are integrated in the facility design and layout to provide personnel protection and environmental protection from exposure to radioactive and hazardous substances.

The footprint for the processing areas is estimated to be on the order of 434,050 ft^2 for the 300 MTHM facility. The process area footprint provides space for processing area support functions including mechanical, electrical, and process control equipment, analytical laboratory spaces; cold storage; and access corridors. The shielded areas are typically placed below grade (to depths approaching 40 feet or more), and the overhead cranes and other support equipment required for unloading and moving shipping casks and processing equipment extend to heights averaging 70 feet above grade. Some buildings may require building heights greater than 70 feet above grade. The process areas may include various tunnels for the transfer of materials between buildings.

Construction estimates (concrete, aggregate, water, structural steel, etc.) presented in this report are based on the footprint provided in Table 21 for an electrochemical processing facility.

Table 21 Electrochemical Processing Building Size Details

	Area (ft^2)
	300 MTHM/year Facility
Total Area of Main Processing Buildings	434,050
Total Support Building Area	1,217,870
Total Building Area	1,651,920

The current footprint for the 300 MTHM/year electrochemical facility assumes only one year of storage for each of the types of waste. To account for the potential for additional storage capacity, the footprint for the electrochemical facility would need to be increased by 20,000 ft^2 every 5 years for HLW storage. It is expected, however, that a disposal pathway for this waste will be available while the facility is operating. If so, additional storage capacity would not be required. A phased construction plan with expandable capacity is envisioned to handle this waste and provide sufficient but not excess storage capacity. New capacity would be built every five to ten years to accommodate a portion of the total waste that would be generated during the subsequent years of production. The need for the construction of new storage space would be reduced or eliminated when disposal paths are decided.

4.1.2 Support Buildings

The major support buildings and structures include, but not limited to, one or more utility/mechanical buildings, storage areas for rail- or trailer-mounted shipping casks, one or more exhaust stacks, one or more fan houses, and reagent storage areas. Other support buildings and structures include a temporary concrete batch plant (approximately 36 acres), temporary construction support facilities, and temporary construction laydown areas (approximately 240 acres) that would be required only during the construction phase. Permanent structures include, but are not limited to, waste handling facilities (LLW, mixed waste, and hazardous waste), analytical laboratory, a radiological laundry, maintenance/machine shop, a cold test facility, a mock-up and training facility, administration buildings, security support facilities, bulk chemical storage, a warehouse, an emergency response/fire facility, personnel access points, a domestic water treatment plant, a sewage treatment facility, radioactive industrial wastewater treatment facility, electrical substations, stormwater retention areas, and parking areas. The total footprint of support structures is estimated to be 1,217,920 ft^2 for the 300 MTHM/year electrochemical processing facility.

Support structures such as laundry and sanitary wastewater treatment plant will have solid and/or liquid effluents. The laundry effluent could include radionuclides or hazardous constituents, and therefore, the effluent from this facility will be transferred to the radioactive industrial wastewater treatment facility. Effluents from the sanitary wastewater treatment plant are not expected to contain hazardous or radioactive material, and therefore, these effluents will be appropriately treated and discharged to permitted outfalls.

4.1.3 Electrochemical Processing Construction Requirements and Impacts

The construction of the 300 MTHM/year facility is estimated to occur over a 12 year period. Construction materials, utilities and wastes are summarized in Tables 22 and 23. The construction materials are estimated based on an estimated facility footprint provided in Table 21. Fuel requirements are primarily based on estimates of the machinery and operating requirements for excavation of the processing building areas and do not include other site preparation (e.g. grading). For the purpose of estimating the air quality impact of construction, it should be assumed that at a minimum the entire site maximum area of 250 acres will be disturbed by grading or other site preparation activities. Estimates of these impacts, in addition to spoil piles, etc., should be added to the excavation impacts presented in Table 23. Water requirements include water for dust suppression, concrete production, and washdown. Aggregate volume does not include the aggregate used in concrete; it is only aggregate used for other purposes such as road base. The concrete estimate includes the aggregate used for the making of concrete. Structural steel includes reinforced steel embedded in concrete in addition to all other structural steel required.

Table 22 Electrochemical Processing Construction Requirements

Material / Resources	Consumption/Use 300 MTHM/year Electrochemical Processing Facility
Peak Electrical Energy (MVA)	
Total	39
Peak Yearly	36
Diesel Generators	Yes – Portable
Number of horsepower-hours of diesel-fueled engines (bulldozers, dump trucks, diesel generators, etc) during the peak year of construction	1,155,500
Number of delivery vehicles during peak year of construction	27,000
Concrete (yd^3)	
Total	850,000
Peak Yearly	150,000
Structural Backfill (yd^3)	
Total	11,000,000
Peak Yearly	2,000,000
Aggregate (yd^3)	
Total	500,000
Peak Yearly	150,000
Structural Steel (tons)	
Total	150,000
Peak Yearly	35,000
Liquid fuel and lube oil (gal)	
Total	5,100,000
Peak Yearly	738,000
Gases (m^3) – i.e. welding gases, etc.	
Total	357,740
Peak Yearly	51,777

Material / Resources	Consumption/Use 300 MTHM/year Electrochemical Processing Facility
Water (gal)	
Total	40,000,000
Peak Yearly	7,500,000
Land (acre)	
Laydown Area Size	240
Parking Lots	60
Material / Resources	
Number of Temporary Concrete Batch Plants	2
Temporary Concrete Batch Plant Area	36
Post Construction Developed Area	250
Employment During Construction	
Construction period (years)	12
Total employment (worker years)	30,099
Peak employment (workers)	4,356

Table 23 Electrochemical Processing Construction Wastes

Waste Generated During Construction	Volume 300 MTHM/year Facility
Hazardous	
Liquid (gal)	15,000
Solid (yd^3)	38
Nonhazardous (Sanitary)	
Liquid (gal)	254,000,000
Solid (yd^3)	53,000
Nonhazardous	
Liquid (gal)	1,100,000
Debris from Site Clearing	22,000 tons
Excavated Material	11,000,000 yd^3
Metal Scrap	23,000 tons
Dunnage	15,000 yd^3

4.1.4 Electrochemical Processing Operations Materials and Wastes

During normal operations, the LWR SNF electrochemical processing facility will process SNF to produce uranium and transuranic products and waste materials. Throughputs and inventories of these processing materials, shown in Table 24, are based on the conceptual process flow sheets that are currently under development. In addition to the processing wastes identified in Table 24, the facility will produce hazardous, sanitary, and other non-hazardous wastes. Estimates of all the operations wastes, including process wastes, are provided in Table 25. Estimates of the operations data are provided in Table 26. Additional information on parameters for Operations is provided in Section 4.2.

Sanitary wastes generated by the sanitary wastewater treatment plant include both liquid and solid effluents. Liquid effluents from the treatment could be used on site for

landscape watering, and process water, and any excess liquids would be discharged to a permitted outfall or evaporation pond. Treated solids would be disposed offsite in an appropriate disposal facility. Radioactive wastes from support facilities such as the analytical laboratory, laundry, storage facilities, etc. would be treated at the radioactive industrial wastewater treatment facility. The liquid effluents from this facility would be discharged to an outfall and the solids would be disposed offsite in an appropriate facility such as a low-level waste disposal facility. Wastes from the machine and maintenance shops would be the same as wastes from similar commercial facilities, and these wastes would be handled in a manner equivalent to these commercial facilities. Other non-hazardous wastes generated at the site include office and cafeteria wastes which will be packaged for disposal at commercial landfills.

Table 24 Estimates of Fuel Processing Materials and Wastes from Electrochemical Processing Operations 300 MTHM/year Facility

Feed/Product/ Waste	Daily Rate (kg/day)	Annual Rate (kg)	Annual Bulk Container Rate	Maximum Storage Duration (years)
LWR Fuel Feed	1,413	339,192	683 assemblies	2
U Metal Product	1,085	260,400	651 drum[3]	1
U/TRU Metal Product (65/35)	58.5	14,040	1,117 can[1]	1
Metal Waste	1,638	393,120	110 canisters[2]	1
Cs/Sr Solidified Waste	721	173,040	60 canisters[4]	1
Lanthanide Solidified Waste	48.5	11,640	4 canisters[4]	1

1 - Can holds 4.4 kg of TRU material
2 - Canister holds 3,600 kg of material
3 - Drum holds 400 kg of material
4 - Canister holds 2,900 kg of material

As with the aqueous processes, estimates of radioactive waste are based on the mass balance calculations performed on the process flows for electrochemical processing. The radioactive wastes generated at the electrochemical processing facility are tentatively classified as HLW, LLW and GTCC wastes, as mentioned in Section 2.3.6, based on the expected half-lives or curie content and currently laws, policies and regulations. The results are shown in Table 25.

It is expected that any mixed (hazardous and radioactive) waste containing organic solvents as the hazardous component would be treated to remove that hazardous component. Such treatment would require a RCRA Part B permit to ensure that the hazardous components are treated and the waste is no longer considered RCRA hazardous or acceptable for land disposal per RCRA.

Storage of radioactive wastes would be designed to accommodate shielding, security, heat loading, inventory, storage duration, and other requirements. Packaging of radioactive wastes will be in accordance with applicable DOE, NRC, and/or DOT regulations.

Table 25 Estimates of Wastes from Electrochemical Processing Operations

Waste Category	Volume 300 MTHM/year Facility	
	Daily	Annual
Low Level		
Liquid (L)	2.19	526
Solid (m^3)	11.1	2,668
Mixed Low-level		
Solid (m^3)	0.12	29
Greater Than Class C (GTCC)		
Solid (m^3)	3.87	928
Mixed Solid (m^3)	0.18	44
HLW		
Solid (m^3)	0.74	178
Hazardous		
Liquid (L)	0.42	100
Solid (m^3)	0.35	84
Nonhazardous		
Liquid (L)	301,370	110,000,000*
Solid (m^3)	22.3	8,137*

* Waste volumes are based on 365 days per year since facility will be staffed year round and nonhazardous waste generation is based more on number of personnel and facility occupation than number of processing days.

Operation of fuel cycle facilities generates several different types of waste. Some are closely related to the process and throughput (e.g. fission products, used solvents, product packages and containers, and excess acid). Other waste streams (secondary wastes) are more closely related to staffing (e.g. sanitary waste) or plant systems and facilities (filters, laboratory wastes, decontamination material). However, the largest source of secondary radioactive waste is typically associated with routine operation and maintenance of the nuclear facilities and equipment. For NEPA purposes, estimates of total waste were derived by combining "process-related" wastes directly related to throughput, with estimates of secondary waste made for each facility. Estimates of secondary wastes considered process conditions, personnel activities (entries into contamination areas and protective clothing requirements), and forecasts of equipment failures, repairs, and replacement. Detailed estimates considering forecasts of routine operations and both major and minor maintenance activities were prepared for each case. Since the total quantity of waste for any given case is impacted by all of these factors, and their relative contribution varies with the type of operation and source materials, comparisons between cases are unlikely to be directly proportional to throughput except for process wastes. Detailed estimating methodology and facility specific assumptions are described the *Waste Generation Forecast and Characterization Study -300 MT/year Electrochemical Processing* (Reference 13).

Table 26 Summary of Electrochemical Processing Operations Data

Data Required	Consumption/Use 300 MTHM/year Facility
Electrical Consumption – daily and annual	1.8 GWh 432 GWh
Peak electrical demand (MVA) – daily	118
Diesel Fuel usage (gal) –annual	66,500
Other Process Gas (N, Ar, etc) – daily and annual	40,000 scf/day 9,600,000 scf/year
Domestic Water (gal) – daily and annual	81,000 19,440,000
Process Water (gal) – daily and annual	3,600 864,000
Cooling Tower Makeup (gal) – daily and annual	99,700 23,928,000
Steam (lb) – daily and annual	100,400 24,096,000
Employment (total workers)	1,473
Number of Radiological Workers	791
Average annual dose to Radiological workers (mrem)	250
Maximum annual Radiological worker dose (mrem)	1000

4.2 Summary of Effluents, Emissions and Reagents during Electrochemical Processing Operations

This section provides a summary of the effluents, reagents, emissions, etc. that are generated and/or used during operation of a LWR SNF electrochemical processing facility. A summary of nuclear materials and products is provided in Table 24. A summary of the wastes from LWR SNF Electrochemical processing is provided in Table 25. There are two sources of liquid effluents from the recycling facility, the annual flow rates are shown in Table 27.

Air emissions from the laboratory operations are shown in Table 28. The radioactive emissions shown in Table 29 include emissions from the head end processes such as tritium, I-129, and Ru-106, and radionuclides released from the waste solidification processes. There are no air emissions from Electrochemical processing such as NOx, CO, etc. The various reagents used in electrochemical processing are provided in Table 30.

Table 27 Liquid Effluents from Electrochemical Processing Operations

Effluent	Source	Annual Flow Rate (L) 300 MTHM/year Facility
Process wastes		No net flow of process liquid wastes
Liquid Effluent from Industrial Wastewater Treatment Facility*	Cleaning, laundry effluent, etc.	7,500,000
Liquid Effluent from Sanitary Wastewater Treatment Facility		98,400,000

* It is anticipated that a portion of this effluent stream will be recycled back to the process to be used as process water.

Table 28 Air Emissions from Analytical Laboratory from Electrochemical Processing

Emissions	300 MTHM/year Facility
	Annual
Radionuclides[1]	<10 mrem/year

1 – Radionuclides are the only expected permitted emissions from the laboratory. All other emissions would be considered insignificant emission under Federal regulations since the emissions are from laboratory used for process quality and control sampling and analysis.

Table 29 Radioactive Air Emissions from Electrochemical processing

Emissions	300 MTHM/year Facility	
	Daily (Ci/day)	Annual (Ci)
Tritium (H-3)	15.4	3,694
Krypton-85 (Kr-85)	3,920	940,800
Iodine-129 (I-129)	0.001	0.28
Ruthenium-106 (Ru-106)	0.40	95.4
Cesium-137 (Cs-137)	368	88,226

Table 30 Reagents Used in Electrochemical Processing Operations

Reagent
Lithium chloride (LiCl)
Potassium chloride (KCl)
Chloride
Glass Frit
Zeolite

5.0 Transportation

The maximum throughput of the various recycling facility alternatives is 800 MTHM of LWR PWR fuel. This converts to approximately 1,820 assemblies per year that would be received at the facility (Table 2). The number of shipments per year depends on how many assemblies are in each shipment. Tables 31 and 32 list some of the NRC-certified shipping casks for transporting fuel per JAI 2005 (Reference 1). Only the transportation casks licensed in the United States have been listed in the tables below. This table shows that the number of assemblies per shipping cask depends on the cask, which, in turn, depends on the maximum burnup and the minimum cooling time before shipment. This analysis will assume that only PWR assemblies are being shipped and that the shipments are made using a rail shipping cask like the NAC International NAC-STC for PWR assemblies. This cask holds 26 PWR assemblies. This conservative approach would produce a reasonable amount of shipments to the LWR recycling facility per year. The transportation data for receipt of fuel is shown in Table 33.

Table 31 Summary of Characteristics of Shipping Casks Used in Canister-Based Storage Systems for Spent Nuclear Fuel[a]

Model	Material of Construction	Manufacture	Capacity[b]	Weight Loaded (tons)[d]	Design Heat Rejection (kw)[d]	Max. Burnup (MWD/ MTHM)
TS-125	Steel – Lead	BNFL Fuel Solutions	21 PWR/ 64 BWR	139	22	40-60
HI-STAR[c]	Multi-Layered Steel	Holtec International	24 PWR/ 68 BWR	139	18.5-20.0	32-37
NAC-STC[c]	Steel - Lead	NAC International	26 PWR[e]	127	12.5-17	43
NAC-UMS	Steel - Lead	NAC International	24 PWR/ 56 BWR	128	16-20	45
NUHOMS-MP-187	Steel - Lead	Transnuclear Inc	24 PWR[f]	136	9.09-14	40-45
NUHOMS-MP197	Steel - Lead	Transnuclear Inc	61 BWR	133	15.8	40

a All casks shown in table are rail casks
b All of these casks are loaded with one multiple assembly canister containing spent fuel assemblies. Thus, the capacity and the heat rejection characteristics of the cask are the same as that of the canister which is carries.
c The NAC-STC can also be used to ship 26 uncanistered fuel assemblies.
d Value depends on specific canister used
e Licensed for canisters containing 36 Yankee Class PWR assemblies and up to 26 Connecticut Yankee PWR assemblies
f Can also accommodate a canister containing 13 damaged PWR assemblies (NUHOMS®-FF canister) as well as a canister containing 24 PWR MOX fuel assemblies.

Table 32 Summary of Characteristics of Shipping Casks for Uncanistered Spent Nuclear Fuel[a]

Model	Material of Construction	Manufacture	Mode of Transport	Capacity[b]	Weight Loaded (tons)	Design Heat Rejection (kw)	Max. Burnup (MWD/ MTHM)[b]
CASTOR YM12S[c]	Forged Steel	GNS	Rail	12 PWR	80	20	40-60
GA-4	SS - DU[d]	General Atomics	Truck	4 PWR	27.5	2.47	34-45
IF-300	SS - DU[d]	General Electric	Rail	7 PWR 17 BWR	70	11.7	35
NAC-LWT	Steel - Lead	NAC International	Truck	1 PWR 2 BWR	25.6	2.5	35
NLI-1/2	Steel – Lead - DU[d]	NAC International	Truck	1 PWR 2 BWR	23.1	10.6	34-56
NLI-10/24	Steel - Lead	NAC International	Rail	10 PWR 24 BWR	97	70	29-36
TN-8/TN-8L[e]-	Steel – Lead	Transnuclear, Inc	Truck	3 PWR	39.3	35.5	38
TN-9[e]	Steel – Lead	Transnuclear, Inc	Truck	7 BWR	39.1	24.5	36.5

a This means that the spent fuel assemblies are bare – i.e., not canistered in large multiple-assembly canisters. However, these casks are capable of handling canisters whose cross-sectional dimensions are only slightly larger than the corresponding fuel assemblies (for failed fuel)
b Some of these values are conditioned on length of cooling time, or only applicable to a fraction of the total cask loading, etc.
c New Design – not currently licensed
d DU means depleted uranium metal
e Overweight Shipment

Table 33 Transportation Data for the Receipt of Fuel

	100 MTHM/year Facilities (Greenfield, F-Canyon, and FPR)	800 MTHM/year Facility	300 MTHM/year Electrochemical Processing Facility
	Expected Annual	**Expected Annual**	**Expected Annual**
Shipments of SNF	9	70	27
Packaging Description	NAC-STC		
Mass per Container	Refer to Tables 31 and 32		
Number of Containers per Transport Vehicle	1	1	1
Number of Shipments per Year	9	70	27
Origin and Destination	From Various Commercial Reactor Sites		
Physical Description of Container Contents	26 PWR Assemblies	26 PWR Assemblies	26 PWR Assemblies
Chemical/Radiological Composition of Container Contents	See Appendix A		

The radioactive waste streams generated will require transportation offsite for treatment and/or disposal. The radioactive waste will go to licensed facilities in accordance with Federal, State and local regulations. Tables 34 through 36 show the anticipated transportation data for the three types of radioactive wastes discussed in the previous section for the three facility alternatives. The number of shipments per year depends on how many containers are in each shipment. The shipping container for the LLW is assumed to be a B-25 container that can hold up to 90 cubic feet of waste; however the containers are typically only filled to approximately 90% capacity. A 15 foot HLW canister is assumed for the HLW shipments and a 10 foot HLW canister for the GTCC wastes. It is assumed that the 10 foot HLW canister for the GTCC waste will be the most conservative for determining shipping impacts. The annual quantities provided in Tables 8-10 were used depending on the waste form where used for aqueous processing. Tables 24 and 25 where used for the electrochemical processing facility. The Cs/Sr waste was not included in the HLW shipment numbers since it will be placed into decay storage for an extended period of time.

Table 34 Transportation Data for the Shipment of Wastes for 100 MTHM/year Aqueous Separations Facilities (Greenfield, F-Canyon and FPR)

	LLW Annual	HLW Annual	GTCC Annual
Shipments of Wastes	148	3	200
Packaging Description	Type A or Type B containers	HLW canisters	HLW canisters
Mass per Container	5,000 lbs	2,900 kg	3,600 kg
Number of Containers per Vehicle	12	5	5
Origin and Destination	To licensed LLW or MLLW treatment or disposal facility	To licensed geological repository	To licensed geological repository
Physical Description of Container Contents	LLW wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)	HLW wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)	GTCC wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)
Chemical/Radiological Composition of Container Contents	Chemical/radiological compositions are presented in the more detailed tables for each process area.	Chemical/radiological compositions are presented in the more detailed tables for each process area.	Chemical/radiological compositions are presented in the more detailed tables for each process area.

Table 35 Transportation Data for the Shipment of Wastes for 800 MTHM/year Aqueous Separations Facility

	LLW Annual	HLW Annual	GTCC Annual
Shipments of Wastes	290	23	369
Packaging Description	Type A or Type B containers	HLW canisters	HLW canisters
Mass per Container	5,000 lbs	2,900 kg	3,600 kg
Number of Containers per Vehicle	12	5	5
Origin and Destination	To licensed LLW or MLLW treatment or disposal facility	To licensed geological repository	To licensed geological repository
Physical Description of Container Contents	LLW wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)	HLW wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)	GTCC wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)
Chemical/Radiological Composition of Container Contents	Chemical/radiological compositions are presented in the more detailed tables for each process area.	Chemical/radiological compositions are presented in the more detailed tables for each process area.	Chemical/radiological compositions are presented in the more detailed tables for each process area.

Table 36 Transportation Data for the Shipment of Wastes for 300 MTHM/year Electrochemical Processing Facility

	LLW Annual	HLW Annual	GTCC Annual
Shipments of Wastes	98	23	270
Packaging Description	Type A or Type B containers	HLW canisters	HLW canisters
Mass per Container	5,000 lbs	2,900 kg	3,600 kg
Number of Containers per Vehicle	12	5	5
Origin and Destination	To licensed LLW or MLLW treatment or disposal facility	To licensed geological repository	To licensed geological repository
Physical Description of Container Contents	LLW wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)	HLW wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)	GTCC wastes (waste forms depend on specific treatment process, but are typically stabilized in a bulk form)
Chemical/Radiological Composition of Container Contents	Chemical/radiological compositions are presented in the more detailed tables for each process area.	Chemical/radiological compositions are presented in the more detailed tables for each process area.	Chemical/radiological compositions are presented in the more detailed tables for each process area.

6.0 Other Separations Facilities

Several European and Asian countries have been recycling commercial LWR SNF for several decades (Table 37). Until recently, the two main commercial reprocessing facilities have been La Hague in France and Sellafield in the United Kingdom (Reference 2). In 2006, Japan placed an 800 MTHM/year facility online in Rokkasho Village. This section will provide the information available on the Rokkasho and La Hague reprocessing facilities.

Table 37 Nuclear Reprocessing Sites for LWR SNF

Reprocessing Site	Reprocessing Capacity (MTHM/yr)	Start of Operations
COGEMA La Hague, France*	1,700	1967 and 1990
Thorp at Sellafield, United Kingdom	900	1994
Rokkasho, Japan	800	2006

* two facilities with different operation dates (UP2-800 and UP3)

6.1 Alternate Separation Processes

All of the current reprocessing facilities use the PUREX or a modified version of the PUREX process. PUREX is an acronym standing for Plutonium and Uranium Recovery by Extraction. The PUREX process (Figure 11) is a proven technology that has been used by the DOE and commercial industry since the 1950's, however it does not meet the GNEP requirement of not separating pure plutonium.

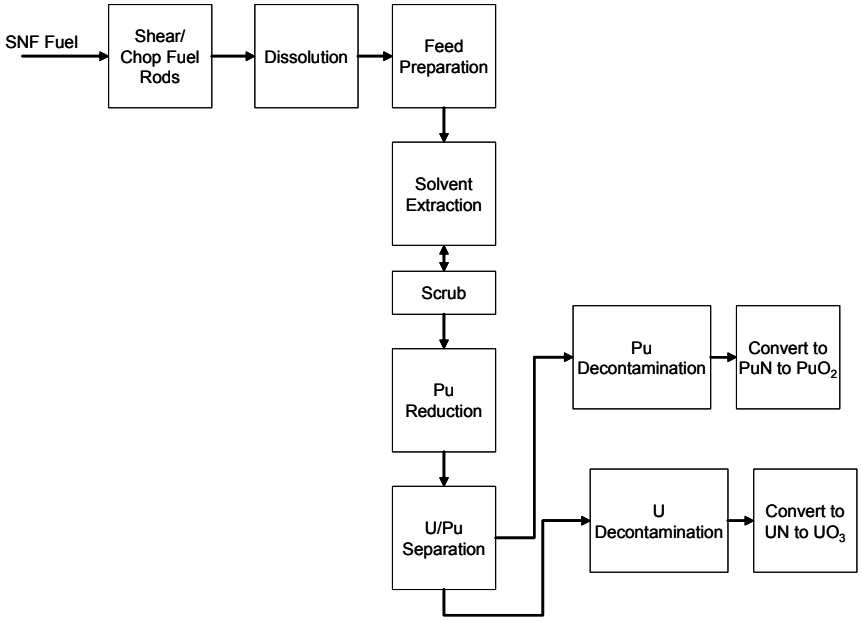

Figure 11 PUREX Flow Diagram (Reference 2)

Technologies are being evaluated such as UREX as a replacement for the traditional PUREX process. The main goal of all the separations process supports non-proliferation efforts by not separating out pure plutonium. Table 38 provides an overview of the other technologies being evaluated beside UREX and electrochemical processing that have already been described in this document (References 3 and 4).

Table 38 Nuclear Reprocessing Technologies

Technology	Description
COEX®	Combined Extraction of plutonium and uranium. The COEX® process removes the most complicated steps in the PUREX process by not separating uranium and plutonium. The waste products are the transuranics (Am, Cm, Np) and fission products. COEX® is a separation technology developed by Areva.
Supercritical CO_2	A solvent extraction method that employs supercritical CO_2 with TBP. Similar to PUREX but without the organic diluent.
DIAMEX	Diamide Extraction process that uses malondiamide for extraction of minor actinides such as Am and Cm. DIAMEX would be used in conjunction with PUREX or COEX®. The DIAMEX process is being worked on in Europe by the French CEA. The process is sufficiently mature that an industrial plant could be constructed with the existing knowledge of the process.
SANEX	Selective Actinide Extraction. As part of the management of minor actinides it has been proposed that the lanthanides and trivalent minor actinides should be removed from the PUREX raffinate by a process such as DIAMEX or TRUEX. In order to allow the actinides such as americium to be either reused in industrial sources or used as fuel the lanthanides must be removed. To date the extraction system for the SANEX process has not been defined, but currently several different research groups are working towards a process. For instance the French CEA is working on a bis-triaiznyl pyridine (BTP) based process.
UNEX	This is the Universal Extraction process which was developed in Russia and the Czech Republic, it is a process designed to remove all of the most troublesome (Sr, Cs and minor actinides) radioisotopes from the raffinates left after the extraction of uranium and plutonium. The chemistry is based upon the interaction of cesium and strontium with poly ethylene oxide (poly ethylene glycol) and a cobalt carborane anion (known as chlorinated cobalt dicarbollide) . The actinides are extracted by CMPO, and the diluent is a polar aromatic such as nitrobenzene. Other dilents such as *meta*-nitrobenzotrifluoride and phenyl trifluoromethyl sulfone have been suggested as well.
NUEX®	NUEX® is a proprietary co-extraction technology developed by the British, and licensed to Energy Solutions, Inc. Like COEX®, NUEX® produces a uranium-plutonium product stream and has no separated pure plutonium anywhere in the process line.

6.2 La Hague Reprocessing Facility

The La Hague reprocessing facility is located on a 740 acres site 15.5 miles west of Cherbourg, France. The facility is operated by Areva NC. The facility processes approximately 1,700 MTHM of LWR SNF per year. The La Hague facility employs about 6,000 people full-time (Reference 5).

The products from the reprocessing are fabricated into a mixed oxide (MOX) fuel. La Hague is capable of recovery up to 99.88% of the uranium and plutonium from SNF. La Hague processes SNF from France and other countries such as Germany and Belgium. From 1990 to 2005, close to 20,000 MTHM of fuel has been reprocessed at the facility (Reference 5).

The La Hague facility is made up of several different workshops (Reference 6). The pilot workshop, AT1, operated from 1969 to 1979 with a nominal capacity of 1 kg/day. AT1 has been dismantled. In 1966, UP2 was originally placed into operation for reprocessing fuel from gas graphite reactors, however in 1976 the plant was upgraded to also reprocess fuel from LWRs. UP2 treated alternatively gas graphite fuel and LWR fuel. UP2 between 1966 and 1987 processed 4,895 tons of gas graphite fuel. UP2 processed its last gas graphite fuel in 1987. Since the upgrade in 1976 until the placement of UP2-800 into service in 1994, about 4,100 tons of LWR fuel was processed in UP2 (also called UP2-400). After 1994, UP2-400 was used only for special campaigns and reprocessing of MOX fuel. All reprocessing in UP2-400 was shut down in 2004.

The current workshops for reprocessing are UP2-800 and UP3. UP2-800 was given permission to process up to 1,000 MTHM/year from the original 800 MTHM of fuel in 2003. UP2-800 was designed to reprocess MOX fuel unlike UP3. UP3 began operations in 1990. UP3 had a nominal capacity of 800 MTHM/year but was authorized in 2003 to process up to 1,000 MTHM/year of fuel. The UP3 workshop was not designed to treat MOX fuel but obtain authorization in 2003 like the UP2-800 workshop. La Hague can store up to 18,000 MTHM of SNF onsite prior to processing.

UP2-800 and UP3 can reprocess LWR SNF made with both natural and reprocessed uranium with a burnup of 75,000 MWD/MTHM or less and with an average enrichment of 4.9 to 5 %. They can also process MOX fuel for LWRs with a burn up of 65,000 MWD/MTHM or less and MOX fuel from fast reactors with a burn up of 120,000 MWD/MTHM or less. In addition, they can process fuel from research reactors.

The plutonium and uranium products are stored separately. Plutonium is stored as an oxide in a stainless steel container. The uranium is stored as a uranium nitrite solution in tanks.

The La Hague facility generates several different waste streams. Table 39 provides information regarding waste generation, treatment and storage, as provided by literature (Reference 6).

Table 39 La Hague Wastes

Waste Stream	Treatment/Disposal (Reference 6)
Gaseous Effluents (tritium, K-85, I-129)	Tritium and K-85 that pass into the gaseous effluents are released in their entirety. Filtration system traps a part of the aerosols. A portion of the iodine is trapped in activated charcoal cartridge filters. See Table 40 for authorized release limits and 2006 discharge levels.
Organic Solvents	Treated at the Atelier MDS (solvent mineralization plant). Ashes are mixed with concrete, grouted and packed in drums for disposal at Andra (LLW disposal). The gases are filtered to separate out the dust (radioactivity stay with dust). The vapors are incinerated and off-gases are scrubbed, filtered and released.
Fission Products and Very Highly Radioactive Acid Solution	Solution that contains fission products and transuranics. Concentrated by evaporation, then vitrified with other wastes. See below for more information concerning vitrification.
Acid Effluents of Medium and Low Radioactivity	Treated and reused or vitrified according to their level of radioactivity
Basic Solutions	Evaporated and the concentrates vitrified with other highly radioactive wastes
Other Aqueous Solutions (gaseous effluents, fuel storage pools, various cleaning operations, and laboratories)	Areva sorts effluents and treats accordingly by one of several processes – co-precipitation, solidification, and evaporation. The sludges from co-precipitation are solidified for disposal. The concentrate from the evaporators are vitrified. The treated effluents are released to the English Channel (ocean) by means of a pipe. The end of the pipe is located in the Raz Blanchard current, 1,700 meters from the coast. The authorized liquid release limits and 2006 levels are in Table 41.
Cladding and Hulls	There were several processes in the past for treatment of cladding and hulls. Up until 1995, the hulls and end pieces from PWR fuel reprocessed in UP3 and UP2-800 were cemented and then stored. In 1995, this process was replaced by storage in water until startup of Atelier de compactage des coques (Hull compaction workshop, ACC). ACC started up in 2001 and compacts the hulls, end pieces, and technological wastes into stainless steel canisters which are stored pending future geological or alternate disposal.
Fines	Fines from shearing and dissolution are vitrified.
Sludges from Precipitation	Solidified and sent to Andra for LLW disposal
Technological Wastes (Plant Wastes)	The AD2 workshop groups and packages the technological waste from UP2-800 and UP3. Most of the cemented technological waste goes to Andra. Wastes high in alpha emitters are sent to ACC where they are compacted with the cladding and hardware.
Resins	Resins are treated at the resin-packaging facility (ACR, Atelier de Conditionnement des Resines). They are concentrated by natural settling; pretreated with calcium to prevent reaction with cement; mixed with cement; and poured into metal drums, which are stored in shielded casks ready for “near surface disposal”.

The vitrified wastes generated at La Hague are poured into stainless steel containers similar to what is used in the United States. The containers hold 150 L of wastes. There are two workshops used to vitrified wastes and each can treat 60 L/hr and produce 600 containers per year. The R7 workshop can store 4,500 containers and the T7 can store 3,600 containers. T7 workshop has a modular extension that can store an additional 4,000 containers. NPH can also store vitrified waste. La Hague has the capacity to store 10 years of production at the nominal rate. As of May 2000, La Hague has 6,759 containers in storage. The vitrified waste includes 99% of the radioactivity of the irradiated SNF but represents 3.5% of their mass (Reference 6). La Hague returns vitrified waste from the reprocessing of foreign fuel to their source country.

Table 40 La Hague Gaseous Releases in 2006 (Reference 5)

Radionuclide	Year 2006 (TBq)	Yearly Limit (TBq)	YTD % of Annual Release Limit
Tritium	67.8	150	45.22
Radioactive Iodines	0.00681	0.02	34.04
Noble gases	242,000	470,000	51.58
Carbon-14	14.20	28	50.70
Other emitters of β and γ	0.0001060	0.0010	10.60
Emitters α	0.00000173	0.00001	17.30

Table 41 La Hague Liquid Releases in 2006 (Reference 5)

Radionuclide	Year 2006 (TBq)	Yearly Limit (TBq)	YTD % of Annual Release Limit
Tritium	11,100	18,500	59.81
Radioactive Iodines	1.34	2.60	51.62
Carbon-14	7.46	42	17.76
Strontium-90	0.216	2	10.80
Cesium-137	0.623	2	31.15
Cesium-134	0.0605	2	3.03
Ruthenium-106	4.80	15	31.98
Cobalt-60	0.210	1	21.00
Other emitters of β and γ	5.24	30	17.45
Emitters α	0.0250	0.1	25.01

In addition to the workshops already mentioned for waste treatment, La Hague has the STE3 liquid effluent treatment facility, AD2 solid waste processing facility and UCD alpha waste treatment facility. La Hague has an active waste minimization program to reduce the amount of waste requiring disposal (References 8 and 9).

In addition to the gaseous emissions in Table 40, La Hague discharged 115.00 tons of NOx and 1,090 tons of SOx in 2001 (Reference 7). No additional data regarding emissions is publicly available.

The following information (Table 42) on operations was obtained from the Areva website, www.cogema.com. The information provided on the website was for 2003.

Table 42 La Hague Operations Data

Data	Annual Use
Facility Floor Area	700,000 m^2
Green Space	35 ha
Water for Fire and Treated Water Elaboration	628,336 m^3
Treated Water (facilities, toilets, demineralized water)	480,000 m^3
Demineralized water dedicated to process	174,000 m^3
Drinking water supplied from District of La Hague	68,000 m^3
Used Industrial water	207,068 m^3
Used Domestic water	50,067 m^3
Electricity	416 GWh
Steam	568,927 tons
Heavy Oil for Steam	30,197 tons (1,114 road trucks)
Average Exposure	0.071 mSv
Maximum Exposure	4.75 mSv
Number of Radiologically Monitored Personnel (Average)	5,680

6.3 Rokkasho Reprocessing Facility

The Rokkasho Reprocessing Plant is located in Rokkasho Village, Aomori Prefecture, Japan and encompasses 938 acres. The facility is operated by Japan Nuclear Fuel Limited (JNFL). The maximum operating capacity is 800 MTHM/year of LWR SNF. The facility began construction in April 1993 and required over 7,000 construction worker working around the clock to complete the facility in 2006. Operations testing began in 2006. The facility employs approximately 2,000 people.

The facility is modeled after the UP3 plant at La Hague in France. The facility uses a modified PUREX separations process (Figure 12) that combines the uranium and plutonium as one of the products. The maximum burnup of the SNF to be processes is 55,000 MWD/MTHM. The SNF must be cooled for more than one year before being transferred to Rokkasho and more than four years before it can be sheared for reprocessing. The facility has wet storage capacity for up to 8,600 BWR assemblies and 3,600 PWR assemblies.

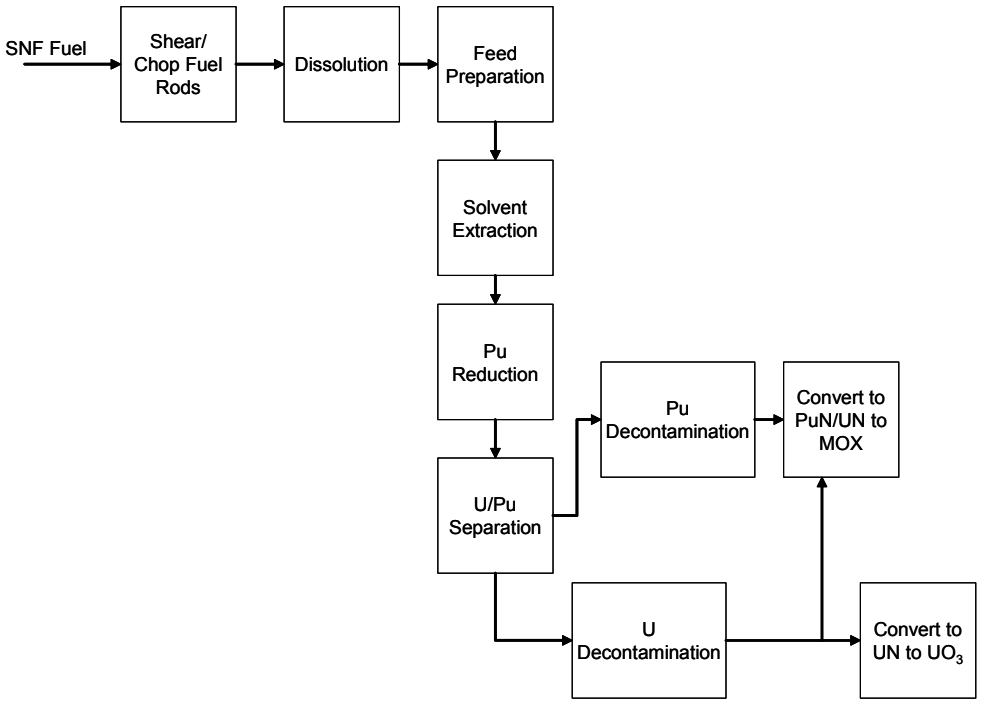

Figure 12 Rokkasho Flow Diagram

The uranyl nitrate solution produced by the PUREX process is converted to UO_3 for storage. Prior to conversion to an oxide, a portion of the uranyl nitrate is combined with the plutonium nitrate stream. The plutonium/uranium solution is solidified to produce a MOX power. Both products are stored until needed. The facility has the capability to store 4,000 tons of UO_3 and 60 tons of MOX powder.

As with La Hague, the Rokkasho facility generates several types of waste streams requiring treatment and disposal. Gaseous wastes are generated from shearing and dissolution, vessel vents, and high activity liquid waste vitrification. Each of the processes generating the gaseous waste has a sub-facility to treat the waste. Treatments include but not limited to NOx scrubbing columns, iodine filters, mist filters, HEPA filters, condensers, and ruthenium absorption columns. The type of treatment depends on the gas composition.

Low activity liquid waste is treated and discharged to the ocean. Low activity wastes consist of low activity evaporator overheads, washroom water, laundry drains, equipment drains, water inside casks, floor drains, etc. There entry into the treatment system depends on their source. The treatment processes used include evaporation, solvent removal, filtration, and desalination. High activity liquid wastes are concentrated then sent to the HALW vitrification sub-facility for treatment and packaging. The packaged vitrified waste is sent to the Vitrified Package Storage Building which has a capacity for 8,200 containers.

The solid low level wastes generated are treated as needed and package for disposal. The Low Activity Solid Waste Treatment sub-facility includes a pyrolysis system for the treatment of spent solvent and an incinerator for other wastes. The ashes from the pyrolysis and incinerator are solidified and packaged for disposal. Other solid LLW are compacted and packaged. The facility has a total storage capacity for 65,500 200-L drums. The hulls and end-pieces are compacted and packaged into 1000-L drums. The facility can store up to 2,000 1000-L drums.

7.0 References

1. JAI Corporation, “Shipping and Storage Cask Data for Commercial Spent Nuclear Fuel”, JAI-582, March 2005

2. International Atomic Energy Agency, “Status and trends in spent fuel reprocessing”, IAEA-TECDOC-1467, September 2005

3. Chandler, Sharon; “Comparison of Reprocessing Methods for Light Water Reactor Fuel”, Thesis, December 2006

4. Wikipedia, “Nuclear Reprocessing”, May 30, 2007 http://en.wikipedia.org/wiki/Nuclear_reprocessing

5. AREVA NC website, www.cogema.com

6. Davis, Mary Byrd; “Nuclear France: materials and sites”, www.francenuc.org

7. The European Pollutant Emission Register, www.eper.ced.eu.int/eper

8. Martin Marietta, “Waste Treatment at the La Hague and Marcoule Sites”, ES/WM-49, April 1995

9. Pradel, Philippe, “Waste Management Optimization : The COGEMA Answer”, Nuclear Engineering and Design, Volume 176 (1997), pp. 181-186.

10. Japan Nuclear Fuel Limited, “Overview of Rokkasho Reprocessing Plant”

11. Washington Savannah River Company,, “Environmental Impacts of Aqueous and Electrochemical Process Alternatives,” EAS-G-ESR-G-00064, March 2008

12. Washington Savannah River Company,, “Waste Generation Forecast and Characterization Study - 800 MT/year UREX+1a,” WH-G-ESR-G-00051, Revision 0, December 2007

13. Washington Savannah River Company,, “Waste Generation Forecast and Characterization Study - 300 MT/year Electrochemical Processing,” WH-G-ESR-G-00054, Revision 0, December 2007

Appendix A-1 - Elemental Composition and Overall Throughput for an 800 MTHM/year LWR SNF Recycling Facility

Element	g/MTHM	Daily Rate (g/day)	Annual Rate (kg/year)
Ag	1.34E+02	446	1.07E+05
Am	7.82E+02	2,604	6.26E+05
Ba	3.18E+03	10,589	2.54E+06
Br	3.59E+01	120	2.87E+04
C	1.73E+02	576	1.38E+05
Cd	3.21E+02	1,069	2.57E+05
Ce	4.20E+03	13,986	3.36E+06
Cm	2.18E+02	726	1.74E+05
Cr	9.41E+03	31,335	7.53E+06
Cs	4.38E+03	14,585	3.50E+06
Eu	3.11E+02	1,036	2.49E+05
Gd	3.70E+02	1,232	2.96E+05
He	8.40E+00	28	6.72E+03
I	4.24E+02	1,412	3.39E+05
Kr	6.08E+02	2,025	4.86E+05
La	2.14E+03	7,126	1.71E+06
Mo	6.42E+03	21,379	5.14E+06
Nb	7.23E+02	2,408	5.78E+05
Nd	7.17E+03	23,876	5.74E+06
Np	1.12E+03	3,730	8.96E+05
Pd	3.17E+03	10,556	2.54E+06
Pm	3.25E+01	108	2.60E+04
Pr	1.95E+03	6,494	1.56E+06
Pu	1.46E+04	48,618	1.17E+07
Rb	5.82E+02	1,938	4.66E+05
Rh	5.97E+02	1,988	4.78E+05
Ru	4.30E+03	14,319	3.44E+06
Sb	4.45E+01	148	3.56E+04
Se	9.75E+01	325	7.80E+04
Sm	1.41E+03	4,695	1.13E+06
Sn	4.28E+03	14,252	3.42E+06
Sr	1.34E+03	4,462	1.07E+06
Tc	1.25E+03	4,163	1.00E+06
Te	9.10E+02	3,030	7.28E+05
U	9.22E+05	3,070,260	7.38E+08
Xe	9.52E+03	31,702	7.62E+06
Y	7.53E+02	2,507	6.02E+05
Zr	2.58E+05	859,140	2.06E+08

Note: Based on 60 GWD/MTHM LWR SNF Fuel and 240 days of operation.

Appendix A-2 –Activity of LWR Spent Nuclear Fuel (60 GWD/MTHM), 5 year cooled)

Isotope	Ci/MTHM	Isotope	Ci/MTHM
Activation Products*		**Activation Products (continued)**	
H3	1.12E-04	Tc99	6.44E-06
Be10	9.36E-08	Tc99m	0.00E+00
C14	3.94E-01	Ru103	8.98E-12
Si32	1.04E-10	Rh102	0.00E+00
P32	2.35E-11	Rh103m	0.00E+00
P33	0.00E+00	Pd103	0.00E+00
S35	4.13E-06	Ag109m	0.00E+00
Ca45	1.15E-04	Ag110	0.00E+00
Sc46	3.60E-08	Ag110m	8.99E-06
Sc47	0.00E+00	Ag111	0.00E+00
V49	0.00E+00	Cd109	9.46E-04
Cr51	9.97E-20	Cd113m	0.00E+00
Mn54	5.57E+00	Cd115m	1.39E-18
Fe55	8.01E+01	In113m	5.01E-03
Fe59	2.84E-17	In114	0.00E+00
Co58	1.41E-10	In114m	3.52E-13
Co60	2.34E+02	In115m	0.00E+00
Ni59	5.65E-02	Sn113	4.90E-04
Ni63	8.00E+00	Sn117m	0.00E+00
Zn65	1.28E-02	Sn119m	8.90E-01
Rb86	0.00E+00	Sn121	0.00E+00
Sr89	1.60E-12	Sn121m	5.03E-01
Sr90	2.09E-03	Sn123	2.45E-03
Y89m	0.00E+00	Sn125	0.00E+00
Y90	2.02E-03	Sb122	0.00E+00
Y91	8.14E-10	Sb124	1.59E-09
Zr89	0.00E+00	Sb125	6.93E+02
Zr93	3.05E-01	Sb126	3.82E-16
Zr95	5.45E+02	Te123m	1.87E-05
Nb91	0.00E+00	Te125m	1.74E+02
Nb92	0.00E+00	Te127	1.27E-08
Nb93m	6.84E-02	Te127m	1.31E-08
Nb94	4.93E-09	Te129	4.16E-21
Nb95	1.25E-04	Te129m	6.35E-21
Nb95m	0.00E+00	I126	0.00E+00
Mo93	0.00E+00	Xe127	1.35E-20
Mo99	0.00E+00	Xe129m	0.00E+00
Tc98	8.76E-13		

* Activation Products from Cladding Only

Isotope	Ci/MTHM	Isotope	Ci/MTHM
Actinides and Daughters **		**Actinides and Daughters (continued)**	
Tl207	0.00E+00	U235	7.82E-03
Tl208	8.82E-02	U236	3.41E-01
Tl209	0.00E+00	U237	3.38E+00
Pb209	0.00E+00	U238	3.07E-01
Pb210	3.65E-08	U240	3.30E-06
Pb211	0.00E+00	Np235	7.28E-04
Pb212	7.26E-02	Np236	1.38E-06
Pb214	0.00E+00	Np237	7.90E-01
Bi210	3.54E-08	Np238	1.62E-01
Bi211	0.00E+00	Np239	6.89E+01
Bi212	7.23E-02	Np240m	0.00E+00
Bi213	0.00E+00	Np240	0.00E+00
Bi214	0.00E+00	Pu236	6.21E-01
Po210	5.16E-06	Pu237	1.09E-11
Po211	0.00E+00	Pu238	1.06E+04
Po212	0.00E+00	Pu239	4.60E+02
Po213	0.00E+00	Pu240	9.51E+02
Po214	0.00E+00	Pu241	1.38E+05
Po215	0.00E+00	Pu242	3.75E+00
Po216	0.00E+00	Pu243	5.88E-06
Po218	0.00E+00	Pu244	2.73E-06
At217	0.00E+00	Pu245	0.00E+00
Rn218	0.00E+00	Am241	1.48E+03
Rn219	0.00E+00	Am242m	3.25E+01
Rn220	7.21E-02	Am242	0.00E+00
Rn222	1.91E-07	Am243	6.92E+01
Fr221	0.00E+00	Am245	0.00E+00
Fr223	0.00E+00	Am246	0.00E+00
Ra222	0.00E+00	Cm241	2.65E-17
Ra223	6.10E-06	Cm242	6.65E+01
Ra224	7.30E-02	Cm243	7.24E+01
Ra225	1.18E-06	Cm244	1.61E+04
Ra226	1.93E-07	Cm245	2.51E+00
Ac225	1.18E-06	Cm246	1.00E+00
Ac227	6.21E-06	Cm247	5.96E-06
Th226	0.00E+00	Cm248	2.68E-05
Th227	6.14E-06	Cm249	0.00E+00
Th228	7.24E-02	Cm250	0.00E+00
Th229	1.18E-06	Bk249	3.31E-03
Th230	8.02E-05	Bk250	0.00E+00
Th231	7.81E-03	Bk251	0.00E+00
Th234	3.07E-01	Cf249	4.98E-04
Pa231	3.38E-05	Cf250	1.81E-03
Pa233	7.87E-01	Cf251	3.29E-05
Pa234m	8.94E-03	Cf252	2.91E-03
Pa234	0.00E+00	Cf253	0.00E+00

Isotope	Ci/MTHM	Isotope	Ci/MTHM
Actinides and Daughters **		**Actinides and Daughters (continued)**	
U230	0.00E+00	Cf254	1.87E-14
U232	9.82E-02	Es253	0.00E+00
U233	3.66E-05	Es254	1.76E-07
U234	1.01E+00	Es255	0.00E+00

** - Fuel, cladding and hardware

Isotope	Ci/MTHM	Isotope	Ci/MTHM
Fission Products **		**Fission Products (continued)**	
H3	9.43E+02	Te125m	1.75E+03
Be7	0.00E+00	I125	0.00E+00
Be10	9.90E-06	Sn126	1.49E+00
C14	2.25E+00	Sb126	2.12E-01
Ge71	0.00E+00	Sb126m	0.00E+00
As73	0.00E+00	I126	0.00E+00
As74	0.00E+00	Sb127	0.00E+00
Se75	0.00E+00	Te127	1.41E-01
Se79	7.21E-01	Te127m	1.46E-01
Kr81	1.44E-06	Xe127	1.84E-16
Rb83	0.00E+00	Te129	1.29E-12
Rb84	0.00E+00	Te129m	2.08E-12
Kr85	1.04E+04	I129	5.62E-02
Rb86	1.36E-26	Xe129m	0.00E+00
Rb87	3.54E-05	I131	0.00E+00
Y88	0.00E+00	Xe131m	1.99E-42
Zr88	0.00E+00	Cs131	0.00E+00
Sr85	0.00E+00	Ba131	0.00E+00
Sr89	7.91E-06	Te132	0.00E+00
Y89m	0.00E+00	I132	0.00E+00
Sr90	1.03E+05	Cs132	0.00E+00
Y90	1.03E+05	Xe133	0.00E+00
Y91	3.36E-04	Ba133	0.00E+00
Nb91	0.00E+00	Cs134	5.99E+01
Zr93	5.83E+00	Cs135	8.43E-01
Nb93m	1.30E+00	Cs136	1.20E-37
Mo93	3.75E-02	Ba136m	0.00E+00
Nb94	1.99E+00	Cs137	1.61E+05
Zr95	3.51E-03	Ba137m	0.00E+00
Nb95	8.00E-03	La137	0.00E+00
Nb95m	0.00E+00	Ce139	0.00E+00
Tc97	0.00E+00	Ba140	1.52E-37
Tc97m	0.00E+00	La140	1.74E-37
Tc98	1.53E-05	Ce141	1.73E-11
Mo99	0.00E+00	Pr143	4.05E-35
Tc99	2.12E+01	Pm143	0.00E+00
Tc99m	0.00E+00	Ce144	1.24E+04
Rh101	0.00E+00	Pr144	0.00E+00
Rh102	7.88E-01	Pr144m	0.00E+00
Rh102m	0.00E+00	Nd144	3.06E-09
Ru103	1.60E-08	Pm144	0.00E+00
Rh103m	1.46E-08	Pm145	0.00E+00
Pd103	0.00E+00	Sm145	0.00E+00
Ag105	0.00E+00	Pm146	0.00E+00
Ru106	72.47E+04	Sm146	0.00E+00
Rh106	2.45E+04	Nd147	1.13E-47

Isotope	Ci/MTHM	Isotope	Ci/MTHM
Fission Products **		**Fission Products (continued)**	
Pd107	2.39E-01	Pm147	3.02E+04
Ag108	0.00E+00	Sm147	4.29E-06
Ag108m	2.02E-02	Pm148	0.00E+00
Ag109m	0.00E+00	Pm148m	1.27E-09
Cd109	1.07E-01	Pm149	0.00E+00
Ag110	0.00E+00	Eu149	0.00E+00
Ag110m	6.73E+01	Sm151	5.51E+02
Ag111	0.00E+00	Gd151	0.00E+00
Cd113m	1.11E+02	Eu152	8.13E+00
In113m	1.79E-02	Gd153	2.61E-01
Sn113	1.78E-02	Eu154	1.62E+04
In114	0.00E+00	Eu155	8.46E+03
In114m	2.24E-09	Eu156	2.88E-31
Cd115m	1.04E-09	Tb157	0.00E+00
In115m	6.73E-14	Tb158	0.00E+00
Sn117m	5.11E-36	Dy159	0.00E+00
Sn119m	4.80E+01	Tb160	7.30E-05
Sb120m	0.00E+00	Tb161	0.00E+00
Sn121	0.00E+00	Ho163	0.00E+00
Sn121m	1.26E+00	Dy166	0.00E+00
Te121	0.00E+00	Ho166	0.00E+00
Te121m	0.00E+00	Ho166m	1.69E-02
Sb122	0.00E+00	Tm168	0.00E+00
Sn123	2.45E-01	Er169	0.00E+00
Te123m	2.39E-03	Yb169	0.00E+00
Sb124	2.50E-06	Tm170	1.34E-05
Sn125	0.00E+00	Tm171	1.13E-03
Sb125	7.29E+03		

** - Fuel, cladding and hardware